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14. ABSTRACT

Rather than focus on the skills of individual clinicians, this project focuses on providing a working environment and system that identifies and proactively addresses errors. This identification of a broad range of system problems has facilitated a better understanding of human abilities and has afforded greater opportunities to help clinicians avoid and deal with error. The analysis of why, when, how and where errors happen provides a window through which it is possible to understand the weaknesses of the modern healthcare system, and thus strengthen it through considered redesign.

Direct, prospective observation and systems analysis methods have demonstrated the value of looking deeper into complex, error-prone systems to develop higher-level quality improvement initiatives. The detailed study of the trauma system and the collection of data prospectively – to understand in depth how healthcare of the near future will look – were thus central in guiding us toward the largest opportunities in trauma care. We conducted interviews and focus groups with a broad range of practitioners to discover their impressions of the problems with the trauma process. Next, we developed an observational methodology, PC tablet data collection tool, and analysis techniques that identified, in great detail, a range of components of care organization that compromise the ability to deliver fast, efficient and safe trauma care. Through a combination of statistical analysis and multi-disciplinary consensus we identified key aspects of process, workplace modification, teamwork, technology and information management that would benefit from re-engineering. By piecing together all of the data elements collected, we were able to target our interventions in order to have the greatest positive impact on the process, and thus the most direct benefit for the future.

We have comprehensively studied the weaknesses of our current civilian trauma system using a bespoke PC-tablet and trained observers. We were able to analyze to an extraordinary degree the flow disruptions that occur during the course of nearly two hundred trauma cases. These data was used to develop a range of interventions focused on simplification, teamwork and communication, and information management, and then to re-evaluate the system following intervention. Training, whiteboard, pre-briefing and standardization interventions were all successful and popular. Headset simulation trials suggested that this was not yet a mature enough technology for further deployment. Ongoing work with an information, patient and process management smartphone application will be complete soon, with a range of exciting possibilities for the future. We are nearing the end of our post-intervention data collection phase. While there is still a substantial amount of careful analysis to be performed, the initial results from the post intervention data period show that the observers have seen 98 cases and recorded 1033 flow disruptions, or a mean of 10.4 FDs per case. In contrast with the original data (20.4 FDs per case), this suggests that the flow disruption rate has nearly halved. This project has demonstrated that detailed systems analysis, coupled with integrated, multi-dimensional interventions developed by clinicians and human scientists working in partnership can substantially improve the quality, efficiency and safety of care along the trauma pathway.

15. SUBJECT TERMS

Human Factors, Flow Disruption, Human Error, Trauma

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Introduction

Cedars-Sinai Medical Center with the support of the Department of Defense Operating Room of the Future grant, seeks to re-engineer teamwork and technology for 21st Century trauma care. Rather than focus on the skills of individual clinicians, this project focuses on providing a working environment that makes the best use of those clinical skills. Our goal is to improve the efficiency and effectiveness of acute trauma care in both the civilian and military settings by introducing innovations in communication, technology, workflow, and behaviors. The overall aims are to simplify the process to reduce errors, improve communication and coordination amongst team members, and enhance the integration and management of information along the trauma pathway.

Trauma care, like other healthcare delivery, has benefitted from an increasing interest in the study of safety, quality, efficiency and human errors. We know that human errors in healthcare are frequent (Kohn et al 2000; Leape & Berwick 2005), and while some directly affect patient outcomes, most do not (de Leval et al. 2000; Wiegmann et al. 2007). However, errors can create a huge range of risks, quality problems, and inefficiencies (Bognar et al. 2008). Furthermore, while a traditional view of error focuses on the responsibilities of individual practitioners, a more modern view is that human error is unavoidable and that faulty systems allow errors to occur, and to eventually cause harm to patients (Reason et al. 2000). The analysis of why, when, how and where errors happen provides a window through which it is possible to understand the weaknesses of the modern healthcare system, and thus strengthen it through considered redesign. Direct, prospective observation and systems analysis methods have demonstrated the value of looking deeper into complex, error-prone systems to develop higher-level quality improvement initiatives. Neither the study of past adverse events and near misses (Olsen et al. 2007) nor interviews or opinions from clinicians alone are sufficient to identify the depth or frequency of these weaknesses (Catchpole & Wiegmann, 2012). This identification of a broad range of system problems has facilitated a better understanding of human abilities and has afforded greater opportunities to help clinicians avoid and deal with error. It has also lead to the development of new systems of work to reduce workload and encourage smoother workflows. Through a multidisciplinary team of experts in process improvement, human factors research, and trauma care, we aimed to improve the trauma system by detecting and reducing human error before a patient is harmed, and redesigning of the systems of care to reduce the likelihood and impact of those errors.

This ambitious re-thinking of trauma care required appropriate solutions to real-world problems that compliment the fundamentally important abilities of clinicians. It was important to our team not to fix something that was not broken, or to apply superficial solutions to deep-rooted problems. The detailed study of the trauma system and the collection of data prospectively – to understand in depth how healthcare of the near future will look – were thus central in guiding us toward the largest opportunities in trauma care. By reviewing hospital policy documentation we mapped the current trauma process. We conducted interviews and focus groups with a broad range of practitioners to discover their impressions of the problems with the process. Next, we developed an observational methodology, PC tablet data collection tool, and analysis techniques that identified, in great detail, a range of components of care organization that compromise the ability to deliver fast, efficient and safe trauma care. Using both human factors and performance improvement methodologies, we collected data on the entire trauma process, from the time the trauma pager was triggered to when that trauma patient was transferred to the ICU, and everything in between. Through a combination of statistical analysis and multi-disciplinary consensus we identified key aspects of process, workplace modification, teamwork, technology and information management that would benefit from re-engineering. By piecing together all of the data elements collected, we were able to target our interventions in order to have the greatest positive impact on the process, and thus the most direct benefit for the future. These interventions were developed, integrated and evaluated for their relevance and effectiveness in both simulation and real world care situations.

This project is a powerful combination of the most comprehensive scientific analysis of trauma care systems ever conducted; a multi-dimensional approach to performance improvement; requirement- and user-centered technology design and evaluation; and broad post-intervention evaluation.

Body

Systems Analysis

In a variety of industrial settings, investigators have used insights from human factors research to optimize the flow of complex work by improving teamwork, technology, training levels or the general work environment. Surgical flow disruptions are events resulting in a pause during the primary surgical task, or a loss of any team member's situational

awareness. There is an empirical link between flow disruptions in the operating room and surgical errors (Wiegmann, 2007). From the systems perspective, flow disruptions are a symptom of a latent failure somewhere within the system. Gaining a better understanding of the frequency and nature of flow disruptions allows for the development of evidence-based interventions (Wiegmann, 2006). We are using the same methodology to identify and address flow disruptions in trauma care in an effort to decrease risk and adverse events.

Care providers completed safety attitude surveys and focus group interviews to identify barriers to optimal performance. Trauma teams activated for high level traumas were also studied prospectively for three months by trained observers to identify flow disruptions using a validated tablet data collection tool. Survey results from 41 staff indicated neutral or positive attitudes towards patient safety, with "speaking up" (71/100) and equipment (76/100) especially positive. Focus groups identified coordination (31%) and protocol deviations (21%) as common causes of frustration, with some confusion over leadership, and little opportunity for debriefing after major events. The observers following 90 cases recorded 1757 flow disruptions (FDs), with a mean of 20.4 (95% CI ± 5.45) per case and 11.9 (95% CI ± 1.78) per hour. Disruptions due to coordination and communication were significantly more frequent than other types. Although no impact on the process was noted in 48% of flow disruptions, 64 of 86 cases (74%) experienced at least one moderate delay or full case cessation. Coordination problems accounted for 37% of these delays. This suggested that leadership and teamwork, patient factors, equipment issues, and communication and coordination within the team and between other essential services reflected weaknesses that might benefit from further consideration and intervention. Direct observation of flow disruptions during trauma care facilitated a better understanding of trauma systems than surveys or focus groups alone.

In combination, these qualitative and quantitative assessments build a picture of the complexity of trauma care and a systemic predisposition to error that is richer and more representative than any single source of data, and a more comprehensive systems analysis than has ever been attempted before.

Systems Redesign

The overall model we adopted for re-engineering improvements had a number of characteristics. Firstly, we recognized that problems originated from multiple sources, and that any one problem might be addressed in several ways. Thus, our improvements needed to be multi-dimensional, and cover a broad range of systems components to integrate technologies, processes and people in the best way. Next, we recognized that the introduction of new technologies, procedures and processes usually increases the complexity of work and training, which reduces efficiency and increases the chance of errors. Thus, our second key interventional characteristic was in achieving simplicity. We have also observed how many healthcare interventions are based on behavioral change (either through training or changes in process). This is especially difficult to achieve, and can be brittle over time, so we sought to keep direct behavioral interventions to a minimum. In order to achieve our goal of developing new ways to work, we also recognized that any approach must be centered on the needs and expertise of the clinicians, based on the data already analyzed that identified key systems problems. This required human-centered designs and iterative approaches to all the interventions we developed, and ultimately mean that some were not as successful as others. Finally, we recognized that care is delivered and will be delivered for the foreseeable future by humans, with technology to assist rather than take over, and that the focus of the development of assistive technologies should be based on what should be done to assist the clinicians, rather than what could be done. This ensured that we directly addressed users needs in a non-complex, sustainable, efficient way.

We have implemented a range of improvements based on the human factors principles outlined above including a whiteboard, standardization, pre-briefing, training, headsets, and a smartphone application. We are nearing the end of our post-intervention data collection phase. While there is still a substantial amount of careful analysis to be performed, here we present an initial view of the data. Overall, we have studied 98 cases in the post-intervention period, of which 87 (88%) of cases were high level and 11 (12%) were lower level traumas. Six cases were OR cases. While this makes our post-intervention cases of slightly lower difficulty than the original sample, they are broadly comparable data sets. In the post intervention data period, the observers recorded 1033 flow disruptions, or a mean of 10.4 FDs per case. In contrast with the original data (20.4 FDs per case), this suggests that the flow disruption rate has nearly halved. Looking at the FD categories, most equipment, training and other FDs have stayed the same, while there are substantial reductions in communication, coordination, interruptions, environmental issues, and patient factors. This is precisely where we would have expected changes to occur based on the focus of our interventions. Though we must be initially cautious of these early results, they are as might have been predicted, and thus are extremely encouraging.

In the following pages, we will summarize our progress on each individual aim included in our statement of work.

Aim 1, Task A: process mapping using practice management guidelines

In developing the process maps, we reviewed trauma policies and procedures, trauma performance improvement and patient safety data, trauma job descriptions, trauma training requirements, and standard trauma forms. The hospital has a large database housing hundreds of policies, each of which could be peripherally related to trauma. In order to ensure the scope of the work was possible, the team agreed to limit the policies included in this deliverable to the ones written specifically for trauma patients and the general surgical policies related to safety (specifically, universal protocol, counts, and informed consent). A total of six process maps were completed; full page versions of the maps are available in the appendix (Appendix Document 1: Process Maps). The first map is a high-level SIPOC (Suppliers – Inputs – Process – Outputs – Customers) that highlights the major events that happen in the trauma process and provides a general overview of all of the players and departments involved in trauma.

We then moved on to the creation of a more detailed map that includes all of the various steps listed in the policies and procedures. The map takes us from the process starting point, when the trauma patient is identified, to post-surgery, when the patient is transferred to the ICU or PACU. Depending on the findings during the ATLS Primary and Secondary Survey, different steps may be taken to stabilize the patient. All of the Primary and Secondary Survey steps are detailed within the process maps.

The process map step has not been completed for Madigan Army Medical Center. The protocol was submitted to the Human Research Protection Office (HRPO) in September 2012. The approval process was delayed at Madigan due their Trauma site survey that occurred in June 2011 and the Chief of Surgery, our primary contact, COL Rush, was deployed in Afghanistan from late May until late August 2011.

The process maps helped the research team better understand the process from end-to-end and also facilitated the development of our observational process. The maps were a quick way to get a foundational understanding of the process as it was defined by hospital policy.

Aim 1, Task B: data collection on process deviations. Quantify adherence

The goal of this step was to understand the process from the perspective of the healthcare workers who work in trauma and to begin to identify deviations between policy (process maps) and perceptions of the process (interviews). Data was collected through interviews, focus groups, and a safety attitude questionnaire.

We spoke to 73 people involved in the trauma process. Our discussions included 24 nurses, 14 doctors, 27 techs, three social workers, three case managers, and two pharmacists. A more detailed breakdown of the interview participants, by department, is noted below.

Interview and Focus Group Participants at Cedars-Sinai:

- Blood Bank 10 participants
- Case Management 6 participants
- Emergency Department 14 participants
- Imaging 3 participants
- Intensive Care Unit 7 participants
- Operating Room 6 participants
- Paramedics 16 participants
- Surgical Specialists 3 participants
- Trauma Team 8 participants

We talked to individuals along the entire continuum of care in order to better understand the process from multiple perspectives. By asking the caregivers to walk us through specific cases, describing every step of the process, we were able to uncover detailed areas and themes that complicated the trauma process. There were two themes that dominated the conversations: communication and role confusion. These ideas came up at a high-level and the interviewers probed to uncover exactly what the participants meant when they mentioned these areas. With communication, the concern

was that the communication channels were unclear. For example, staff did not know who was responsible for calling the blood bank or who was supposed to enter orders in the emergency department. There was confusion about whether the primary and secondary surveys had been completed during a trauma because the steps were not explicitly called out by the physician in charge. Finally, distractions, particularly in the form of superfluous noise, reduced the amount of information that is transferred from team member to team member during a trauma. The military experiences similar obstacles; the noise on the battlefield, with gunfire and helicopter protection overhead, can make communication very difficult.

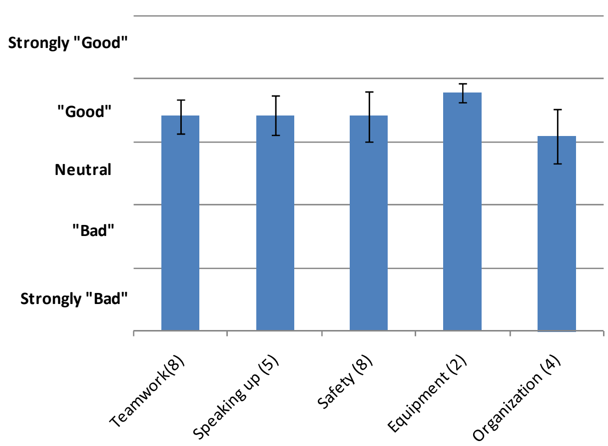
Role confusion was uncovered when we heard many people mention a “captain” or “leader” in their responses to our questions, but the majority struggled to give a specific title associated with the captain or leader. In other words, it was not clear who is, or should be, in charge of the room. When two attendings are in the trauma bay, one from the emergency department and one from trauma surgery, there was no clear rule for who is in charge. Similarly, in military trauma, roles and leadership may perhaps be unclear when mixing military ranks with the healthcare hierarchy. It will be informative to incorporate the findings from the Madigan interviews once they are complete.

Out of all of the questions, we received the most feedback when we asked: what frustrates you the most about the trauma process? Caregivers could easily remember and recount the times when they were frustrated. The item noted the most was a lack of coordination among the various departments, specifically coordination among the ED, Imaging, OR, and the ICU.

In talking to the trauma clinicians, we also learned that debriefings rarely occur. This result is important but not expected, since debriefing may be a central component of quality improvement, learning, and coping with stress – yet in mainstream trauma healthcare it is frequently omitted, and nearly never conducted as a a team. Here, we also see a strong tie to Landstuhl Regional Medical Center (see Landstuhl Visit summary later in the document). Our visit to Landstuhl included a discussion of After Action Reviews and the Resiliency Team. The Resiliency Team is in place to help the medical team deal with all of the trauma and loss that they witness in addition to learning from each of the situations. We felt it to be an excellent program that a civilian hospital could learn a great deal from. Debriefings are a key learning and coping tool and they can always be improved. We suspect two barriers to debriefing are having the time, and ensuring feedback and resulting action occurs, so we are interested in taking this on to develop smarter and better ways to debrief.

Finally, we administered a safety attitude questionnaire to 41 healthcare workers at Cedars-Sinai Medical Center in order to assess the current safety culture. The questions were categorized into five domains: Equipment, Organization, Safety, Speaking Up, and Teamwork. Results from the completed surveys are summarized in the graph below. The trauma team tends to have a positive attitude towards safety and show especially high scores and agreement on equipment.

Figure 1: Safety Attitude Questionnaire Results



Levels of Agreement

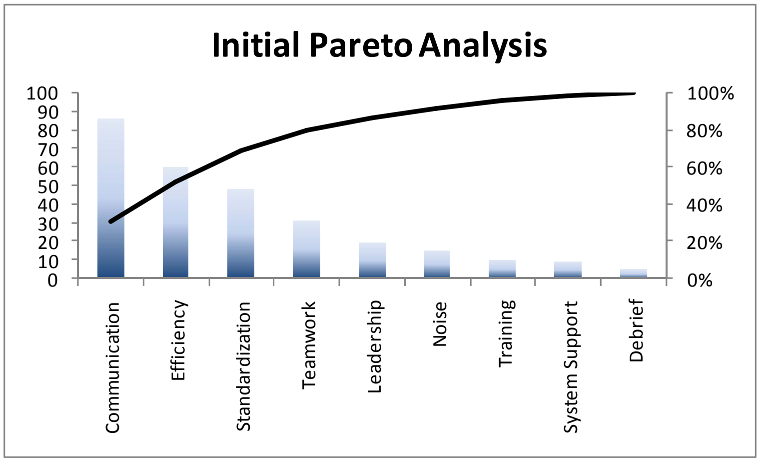
Safety	r = 0.31
Organization	r = 0.23
Equipment	r = 0.77
Speaking up	r = 0.19
Teamwork	r = 0.34

The detailed notes from the interviews and focus groups as well as the results from the safety attitude questionnaire helped to inform the development of the prospective observations tool which will be discussed later in the report.

Aim 1, Task C: identify process deviations, attributing deviations to people, technology, and the environment

We developed a Pareto chart based on the process maps, interviews, focus groups, and safety attitude questionnaire. The themes cut across all three of our areas of interest, specifically people, technology, and the environment. We have included definitions for each bar, pulling the definitions directly from our data. The Pareto will be updated when we are able to collect data from Madigan Army Medical Center.

Figure 2: Pareto of Process Deviations



Communication
speak out loud when conducting the surveys, give the OR a heads up that you are coming, better communication among the various specialty teams, it would be nice to learn about the entire trauma process, reliable information from the field, verbally review what everyone is doing, we gave back the trauma pager b/c it didn't tell us anything

Efficiency
getting an operating room is a problem, better placement of supplies, add propofol to the pyxis, trauma cart available, dedicated trauma bay, samples sent to the wrong lab, lab instruments down, this place moves supplies all of the time, elective cases are in the scanner, waiting for a transporter, PACS in the trauma room but have had problems with the plain films coming up too slowly, waiting for blood

Standardization
stop doing emergent cases at night, primary survey needs to be more automatic, have a family conference within 48 hours, we used to have three tiers of trauma and it worked better, nobody called for a massive transfusion protocol, peds patient cared for in adult ICU, the surgeons like to skip steps

Teamwork
it would be nice to know the names of the people we are working with, interference from observers – no one took charge and told them to leave, proactive, doctor signed off on the Medi-Cal pending paperwork very quickly, great anticipation by everyone

Leadership
surgeon communicated a plan of care, involved the entire team, Sue in the ED is aggressive and she keeps us informed, decisive, no yelling, took charge but was collaborative, the attending had a plan and it meant the team was prepared, totally uncoordinated

Noise
confusion, many people involved, crowd control, doctor were yelling

Training
SICU nurses used at another hospital, people understanding their roles, techs are trained in many different specialties which is helpful, residents do not know the correct order of things sometime our proficiency of equipment use is slow b/c we don't use it often

System Support
trauma is an inconvenience to everyone but the patient and the trauma surgeon, Cedars doesn't have a different pace for trauma

The researchers noticed differences between that which is written in the policies (process maps) and the perceptions of what happens in reality (interviews). Our next aim allowed us to gain the third and final perspective: reality.

Aim 1, Task D: conduct prospective data collection

Surgical flow disruptions are events resulting in a pause during the primary surgical task, or a loss of any team member's situational awareness. There is an empirical link between flow disruptions in the operating room and surgical errors (Wiegmann, 2007). From the systems perspective, flow disruptions are a symptom of a latent failure somewhere within the system. Gaining a better understanding of the frequency and nature of flow disruptions allows for the development of evidence-based interventions (Wiegmann, 2006). Flow disruptions collected in a single case hold little validity for indicating system failures because there are many variables such as team member personality and individual patient factors that influence the progression of any specific case. In contrast, flow disruptions that indicate systemic failures will resurface across cases, revealing areas that warrant further investigation. Some benefits of flow disruptions as a metric include; the ability to capture systemic failures of any type and the ability to acquire a baseline measure.

Based on the information obtained through the process maps and the interviews, our human factors collaborators modified a PC data collection tablet in order to capture flow disruptions (Appendix Document 2: Tablet PC Data Collection Tool Screen Shots). We engaged six medical students and two PhD candidates to conduct the trauma observations. The observers were trained by human factors experts as well as crew resource managment experts in order to help them identify key flow disruptions that occur during trauma cases.

There was concern among the clinical researchers that the student observers' lack of clinical expertise may impede their ability to pick up clinically relevant factors that impact a case. In order to address this concern, we incorporated our anesthesia fellows into the observational process. The fellows observed alongside the students during a proportion of cases, allowing comparison between experienced and inexperienced medically trained observers, but also allowed for

reliability testing that ensured the level of error in our measurements was accurately tracked and thus scientifically validated.

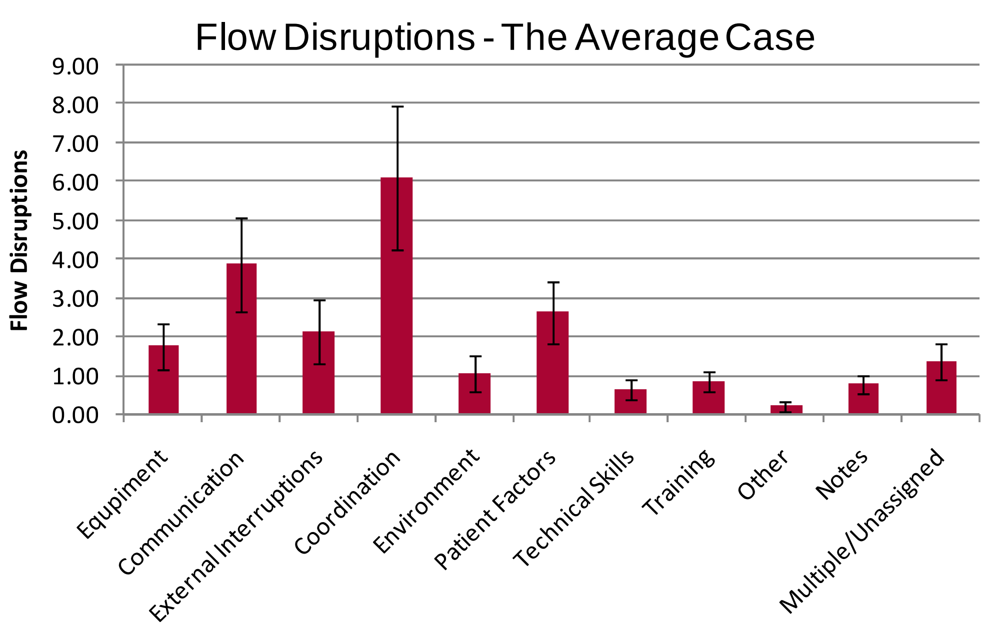
Trauma teams activated for high level traumas were studied to determine the frequency, cause, and impact of flow disruptions. Observers followed patients from the ED to ICU, ward, or discharge. We collected data on the number, type, timing, and severity of flow disruptions.

Our data set has a total of 90 cases. Fifteen cases were trauma level 100s (critical trauma activations), while 75 cases were trauma level 200s (trauma activations). The detailed criteria for a trauma activation can be found in the appendix (Appendix Document 3: Trauma Activation Criteria). A total of eight cases went to the operating room. Of the eight that went to the operating room, four were 100s and four were 200s.

A total of 1757 flow disruptions were recorded (11.8/case). The rate of flow disruptions among high-level and low level trauma activations was 16.0 FD/hr (95% CI: + 6.6 FD/hr) and 10.9 FD/hr (95% CI: + 1.6 FD/hr), respectively. Among the three phases of trauma care, the frequency of flow disruptions was highest in the OR (mean: 24.2 FD/hr, 95% CI: + 14.4), followed by the CT scanner (mean: 14.4 FD/hr, 95% CI: + 2.7) and the trauma bay (mean: 11.0 FD/hr, 95% CI: + 2.0). High-level traumas experienced a significantly higher rate of flow disruptions within the imaging phase of care than low-level traumas (p=0.0008). The most common flow disruptions are: Coordination (29%), Communication (18%), Patient Factors (12%), External Interruptions (10%), and Equipment (8%).

This study is one of the first and largest to objectively document that FD in trauma care occur at a relatively high rate, particularly within the operating room among higher-level traumas. Further examination of the types and nature of was used in the design of interventions to improve the efficiency and safety of patient care.

Figure 3: Pareto of Process Deviations



Examples of the various flow disruptions, taken verbatim from the observers' notes, are listed below:

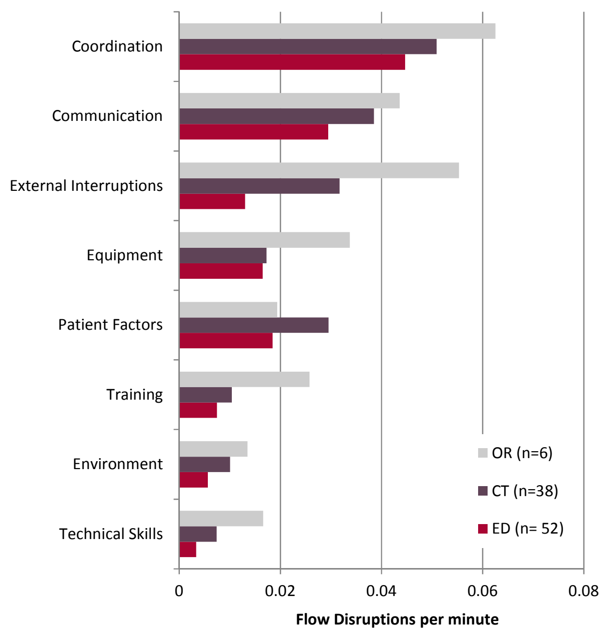
- ***Coordination*** = "another patient was in the CT room on arrival"
- ***Communication*** = "tech had to ask EM doc again if he wanted the left or right arm"
- ***Patient Factors*** = "Pt shaking, cold, saying "ouch" catheter hurts"

- ***External Interruptions*** = "PT in the neighborly room being loud"
- ***Equipment*** = "Tool hanging from the ceiling in way of staff"
- ***Training (Instruction)*** = "Attending explaining the care plan to resident"
- ***Environment*** = "Pt stuck in hallway for a minute because another is coming through"
- ***Technical (Skills)*** = "Pulse tube became lose and the r-tech had to quickly adjust it"

Trauma level 100s had a slightly longer duration and more flow disruptions than trauma level 200s, but the rate, the time between flow disruptions, is approximately 10 minutes for both 100s and 200s. Cases that went to the operating room had a longer duration and more flow disruptions than cases that did not go to the operating room. The rate of flow disruptions during operating room cases is higher than non-operating room cases.

Figure 4 shows the high-level Human Factors categories and the rate of flow disruptions recorded in each phase of the trauma: emergency department (ED), computed tomography (CT), and operating room (OR). The rate of flow disruptions was the highest in the operating room, followed by CT, and then the emergency department. While coordination and communication flow disruption rates were prevalent in all three phases of the trauma, equipment and external interruption rates increased in the operating room while patient factor rates increased in CT.

Figure 4: Flow Disruptions per Minute



Several cases stand out with a very high number of flow disruptions. Case 58 was a motorcycle accident and had 155 flow disruptions. Delays led to frustration and teamwork problems. The problems were exacerbated by equipment and workspace issues. The key themes that were observed included: lack of teamwork, workspace issues in the operating room, a delay in getting to CT, a delay in the surgery start, and general distractions.

We found that case 58 had more coordination and communication problems, as well as external interruptions when compared to the rest of our sample. Case 58 also had fewer patient factors than the rest of our sample. Examples of the specific flow disruptions observed during this case include: the team waiting for the orthopedic representative who was stuck in traffic, the nurse could not locate the Bovie, the trauma pagers go off as another patient enters the emergency department, and the team was navigating around blood and garbage on the operating room floor. Two specific quotes noted during the case highlight the team dynamics in the room: "the next person who touches the power supply gets their hand chopped off" and "Do you know about seniority? I have been here for 25 years."

Case 88 was an auto versus pedestrian case that had 162 flow disruptions. The patient was sick (GCS 3, internal bleeding), it took 30 – 40 minutes to get blood, the workspace was tight in the operating room (a nurse tripped a few times), the patient was intubated in CT, and the suction malfunctioned. This qualitative "story" that came out of the flow disruption descriptions provides clinical relevance and is vital to understanding the importance of flow disruptions.

We have completed some additional sub-analyses, specifically from the Clinical and Quality perspectives, to further understand the data.

Clinical Data Analysis
A Resident and Surgical Attending reviewed all of the flow disruptions to assess the clinical impact. The intent of the clinical review was to determine which flow disruptions had a negative impact on the case, defined as a delay in care, as determined by a physician. A rating system of 0 – 3 was used (0 = No Clinical Impact, 1 = Minimal Clinical Impact, 2 = Moderate Clinical Impact, 3 = Severe Clinical Impact).

A total of 27% of the flow disruptions had no impact on the case time, 57% had a minimal impact, 11% a moderate impact, and 5% a severe impact. Examples of severe clinical impact flow disruption taken verbatim from the observations include:

- "There is no head/neck person in office to read scans so Attending had to look for someone to do it"
- "Still unable to reach Ortho Doc. Attending calls ED- had wrong Ortho Doc on call"
- "RN ask again for CT 'Good thing [this is] not a true emergency'"
- "Requesting blood x 2 not here"

The clinical analysis highlighted an opportunity for improvement in CT: 48% of the cases had a major delay associated with CT. The most common reasons noted for the CT delays were: scanner not ready, scanner occupied, orders not entered, technologist was inexperienced, the patient was moving during the scan, and a transport monitor was not available. In civilian trauma, unlike battlefield trauma, the CT scan is a key diagnostic tool. In both civilian and military hospitals in the States, surgeons use the results to solidify the plan of care. Getting results quickly is critical; a lack of efficiency leads to a delay in care.

Figure 5: Examples of Major and Minor Clinical Flow Disruptions

Major Clinical Flow Disruptions	Minor Clinical Flow Disruptions
▪Blood not ready	▪Phone calls
▪Cannot get hold of OR nurse	▪Scribe nurse asks for findings to be repeated
▪Equipment missing/hard to locate	▪Waiting for interpreter
▪Team dynamics with anesthesia	▪Cords/IV tubing getting tangled
▪Suction not attached or full	▪Extraneous conversations
▪Intubation in CT	▪Who's trauma chief/resident?
▪Workspace Issues	▪Issues with monitor (locating, battery dying, missing cords/connections)
▪Patient uncooperative/ combative	
▪Communicating with ortho or waiting for ortho	
▪Physicians repeating orders	

An average of 30 m inutes (95% CI ± 3 mins; range 7-98 mins) was spent in the CT scanner, with a mean of 14.5 (95% CI ± 2.7) flow disruptions per hour. Coordination (34%), communication (19%), interruptions (13%), patient factors (12%), and equipment (8%) were the most frequent disruption types. Clinical and observer impact scores were in general agreement ($p<0.0001$).

A summary of the themes uncovered during the clinical review is included in figure 5. Major clinical flow disruptions include the moderate to severe impact disruptions while Minor flow disruptions include minimal to no impact disruptions.

Time Analysis
The Clinical review highlighted the importance of efficiency and time. Efficiency is an important measure in trauma care. Quicker diagnostics have been proven to have a positive impact on trauma case outcomes. Therefore, time is an important metric to understand and improve.

Based on the 90 cases that we observed, it takes an average of 23.3 minutes from the time the patient enters the emergency department to when he/she is taken to CT. Once in CT, patients spend an average of 30.8 minutes in imaging. For patients that needed to go to the operating room, a small number in our data set, it took 126.2 minutes from the time the patient entered the emergency department to when the patient entered the operating room. We found very little difference in time spent in each phase (emergency department, CT, operating room) between the more acute 100 trauma cases and the less acute 200 trauma cases.

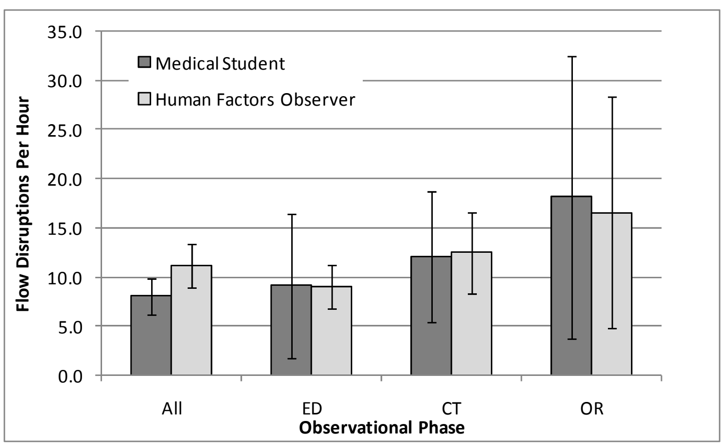
Quality Data Analysis
For our final sub-analysis, a Lean Six Sigma Master Black Belt reviewed all of the flow disruptions to assess the impact on Quality and to bring the Clinical and Human Factors analyses together. The flow disruptions were categorized based on the outcomes from both the Human Factors and Clinical reviews. From the Clinical review, the key issue areas highlighted were: CT, patient factors, and workspace/equipment. From the Human Factors review, the key issue areas highlighted were: communication, coordination, and external interruptions. The goal of this final analysis was to develop a summarized data set for the root cause analysis that incorporated three viewpoints: Human Factors, Clinical, and Quality.

Communication was the most common flow disruption, representing 24% of the sample, followed by workspace at 20%, coordination at 17%, external interruptions at 16%, CT at 13%, and patient factors at 10%. To further understand the data, subcategories were added. For example, Getting to CT was further broken down to include: scanner not available, delays due to monitors and tubes, missing orders, obstacles during transport, and unclear next steps. Examples of the subcategories for communication are: transfer of information, volume of people/noise, extraneous conversations, repeat, teamwork issues, and verification. The subcategories are detailed in the appendix (Appendix Document 4: Quality Flow Disruption Analysis for RCA – Subcategory Details).

The subcategories gave us more focus and further highlighted the areas of opportunity. By focusing on the top nine subcategories (equipment and supply availability, reducing phone calls, improving information transfer, etc), we could address 68% of the total flow disruptions. This data formed the foundation of our root cause analysis.

The Influence of the Observer
As part of our research method design, we wanted to test the impact of various observers. Would Human Factors PhD students and Medical Students see the trauma cases differently? Our data showed that there were extremely minimal differences between the two types of observers (figure 6). We believe that eight hours of classroom training along with dual observation training led to the high inter-rater reliability.

Figure 6: Observer Comparison



Visit to Landstuhl Regional Medical Center

To better understand the military trauma process and to hear first-hand about the types of improvements that could make a difference at Landstuhl, our project manager took the opportunity to visit Landstuhl, Germany in March 2011 during another European assignment. She was in Italy working on her Master's thesis and decided to make the short trip up to Germany to meet and talk to the Landstuhl team. She spoke to multiple team members involved in the trauma process including: Insel Angus, ICU RN; LTC Raymond Fang, MD, Trauma Medical Director; MAJ Kenny Harryman, RN, Head Operating Room Nurse; Connie Johnson, Trauma Coordinator; Kathie Martin, RN, Trauma Program Director; and LTC Lisa Toven, OR RN.

Landstuhl was a Level II Trauma Center at the time of the visit (as of Fall 2011, they are now a Level I trauma center) with eight operating rooms and 12 intensive care unit beds. The most common injuries seen were neck and lower extremities. The average soldier length-of-stay was three days. Landstuhl functions with a diverse, transient team that includes Air Force, Army, Navy Reserves, and local civilians.

We asked the Landstuhl Trauma Team what they would do to improve the trauma process and they had many insights to share with our research team. In an ideal setting, everything would be available at the point of care, standardization would be more prevalent, and technology would be better utilized to improve efficiency and o utcomes. We incorporated these ideas into our root cause analysis which led to the development of our interventions.

Visit to Madigan Army Medical Center

Bruce Gewertz, MD, PI, Ben Starnes, MD, and Jennifer Blaha, Project Manager, visited Madigan Army Medical Center in May 2011. They met with the surgical leadership team and discussed the latest improvements that the Madigan team is working on. A great deal was learned about how they are executing on the Team STEPPS program. Additionally, we toured the hospital and si mulation center. The Madigan team, including COL Robert Rush, MD, LTC Scott Steele, MD, LTC Niten Singh, MD, LTC Matt Martin, MD, and Linda Casey, the Trauma Coordinator, has been working on the IRB requirements in order to complete the interviews and focus groups at their hospital.

Aim 1, Task E: perform root cause analysis

A root cause analysis was completed with the participation of 18 members of the team. The theory behind root cause analysis is that problems are best solved by attempting to address root causes as opposed to addressing the immediately obvious symptoms. By focusing interventions on root causes, it is more likely that the problem will be prevented.We showed a short video on the root cause analysis for the Exxon Valdez disaster. Through the media coverage of the Exxon Valdez event, most people believe that the drunken captain was to blame for the crash. A careful review of the incident reports, highlighting the various causes, paints a very different picture of the event and offers targeted solutions to the real root causes of the crash. This was a powerful example of the importance of identifying the real root cause of a problem or delay and gave the team a tangible example that they could then translate into our flow disruption delays.

The results from the root cause analysis session are summarized in the graphics below. The end result from the session was a list of possible interventions that would address the systemic problems that we had uncovered through the interviews, focus groups, and observations. The list of potential solutions was used as the basis to determine the areas of high impact and high priority and ultimately drove our intervention road map.

Figure 7: Coordination Delay Root Cause Analysis Summary

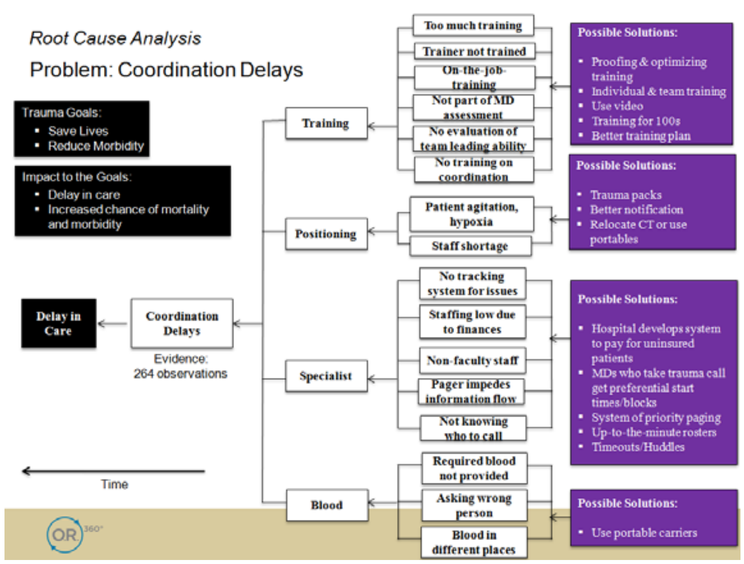


Figure 8: Equipment & Supply Delay Root Cause Analysis Summary

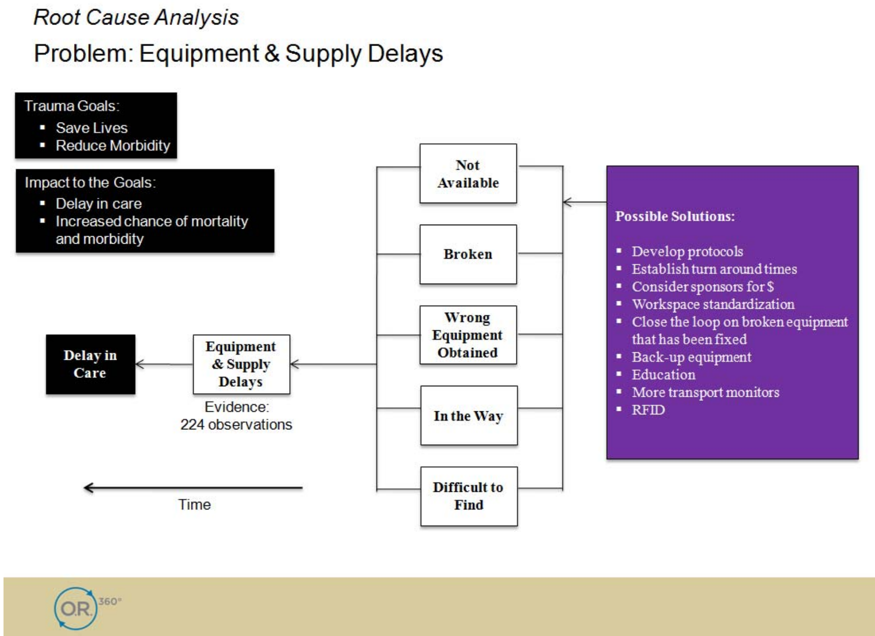


Figure 9: CT Delay Root Cause Analysis Summary

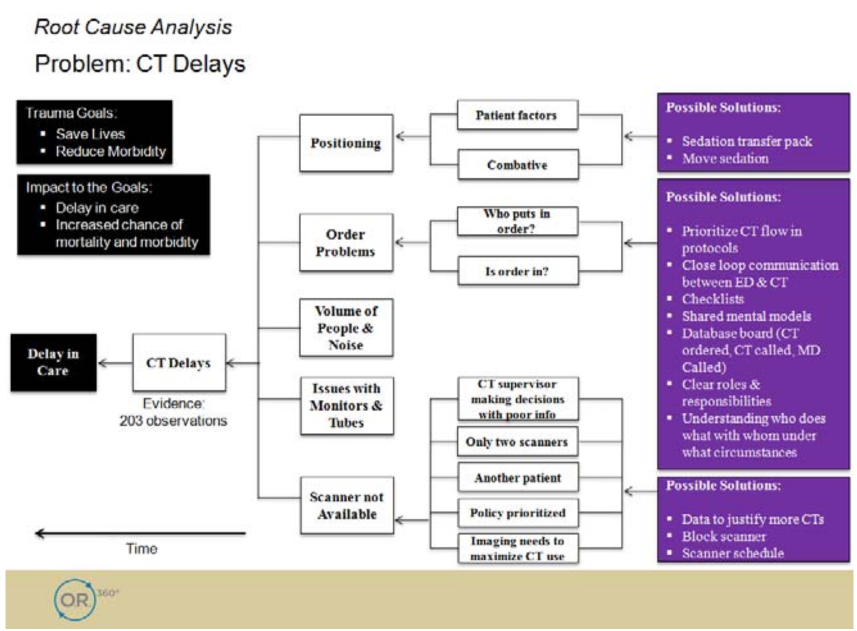
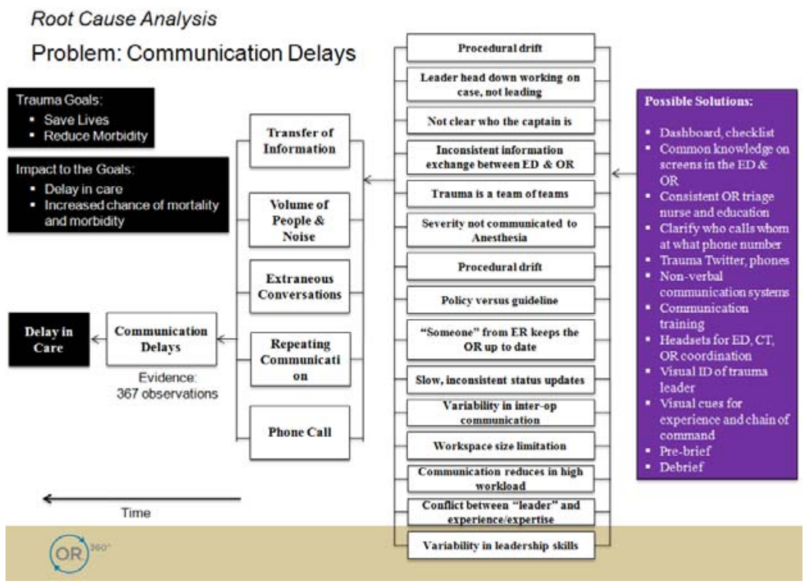


Figure 10: Communication Delay Root Cause Analysis Summary



Aim 1, Task F: feedback to current stakeholders

Feedback has been ongoing throughout the project. We continue to have weekly subgroup meetings, monthly conference calls with the entire collaborative team, as well as bi-annual face-to-face meeting at Cedars-Sinai

We also present to the Cedars-Sinai Trauma Performance Improvement Committee, ED Performance Improvement Committee, and the Department of Surgery Performance Improvement Committee on a regular basis to update the teams on any elements of our research that will affect their respective departments.

Our Sharepoint site (eRoom) houses all of our collaborative documents and allows team members to easily keep up with the latest activities and progress. The site is available to both internal Cedars-Sinai team members as well as our outside collaborators.

Aim 1, Task G: determine areas of high priority/high impact/high risk

Aim 2: Task A: design potential interventions

The outcome of the root cause analysis process was a list of potential interventions that would likely impact the high volume flow disruptions. Several interventions stood out as they were a recurring suggestion from each team. The root cause analysis process had narrowed down our improvement efforts and solidified our intervention plan.

The status of each project is detailed below. The following is a list of our interventions:

- Whiteboard implementation leading to a data dashboard
- Pre-briefing
- Lean workspace standardization
- Trauma transport medication pack
- Teamwork and leadership training
- Headsets

Aim 2: Task B: develop protocols, Aim 2: Task C: tests of change in simulation

We are currently monitoring the implementation of our interventions; we are collecting data to quantify their impact. The details of each project are detailed below.

Intervention: **Lean Workspace Standardization**

Observations and interviews highlighted that the equipment & supplies in the trauma bays are not standardized, leading to delays. There are four trauma bays at Cedars-Sinai; we decided to focus our efforts on standardizing Bays 2 & 3. We chose these rooms because they are larger than the others and are preferred by the trauma team. We began by developing a current state map of the trauma bays and then requesting feedback for all team members involved in trauma. The result was a color-coded bay that allows staff to more quickly locate the supplies and equipment that they need during a trauma.

For the surrogate measure, we completed before and after spaghetti maps that depict the time and distance covered during specific trauma scenarios. The maps show the distances traveled by four different healthcare workers involved in a trauma case (four nurses and one nurse aid). The results are available in the next section.

Intervention: **Whiteboard**

Observations and interviews highlighted that the nursing staff get interrupted numerous times at the beginning of a trauma case. As each new team member arrives, the nurses are asked about the mechanism of injury, patient age, etc. In an effort to reduce these interruptions, we mounted a whiteboard in the trauma bay to display key pre-hospital information. The team wanted to begin with a whiteboard as a precursor to a more technological solution. The goal is to first prove with a low-tech test that having basic information available is a benefit to the trauma team prior to moving to a high-tech solution.

The whiteboard includes labels to trigger the key information that is needed for the team: patient age, gender, mechanism, pre-hospital vitals, and field treatment. The radio nurse (MICN) is responsible for filling in the patient details based on the information obtained from the medics. Gaining buy-in from the MICNs was easy since they immediately saw the value of writing the information once and then eliminating the numerous repeated questions from the trauma clinicians. The Environmental Services team is responsible for erasing the board during routine room cleaning between patients.

The buy-in from both the trauma surgeons and the emergency department staff has helped make the whiteboard an integral tool for this very fluid team. The whiteboard has formed the model for the technological development of a electronic smartphone application, outlined below, to distribute this information more widely.

For each one of the interventions, we have selected a surrogate measure to supplement the flow disruption data. For the whiteboard, we are looking at the following surrogate measures: what data are being recorded on the board, who wrote the information, was the information current for the current case, and was the information on the whiteboard before the trauma team arrived? Data on the surrogate measures is available in the next section of the report.

Intervention: **Pre-Briefing**

The team theorized that implementing team briefings will reduce communication and coordination flow disruptions. The briefings will help clarify roles and responsibilities, facilitate socialization of new members, and help define the plan of care. A great deal of research has been published on this topic so the team began with a literature.

Given the paucity of research on pre-briefing for trauma care, our literature search result revealed several papers on pre-briefing in surgery. While the surgery (or operating room) domain is different, we posit that the trauma care process can benefit from the results and utilize the recommendations and best practices that surgery provides.

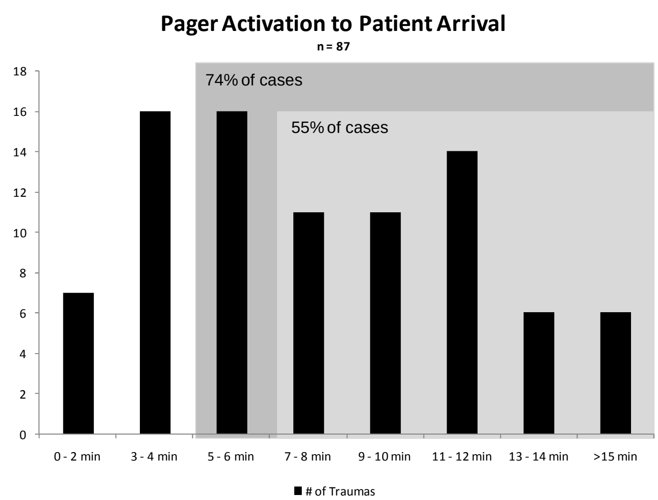
Across the several studies identified in the literature review, pre-briefing implementation (1) decreased non-routine events (Yael Einav et al., 2010) and/or surgical flow disruptions [reduction procedural knowledge disruptions and miscommunication] (Hendrickson et al., 2009), (2) highlighted potential patient problems and improved communication (Ali, Muhammad et al., 2011), and (3) reduce unexpected delays and a reduced communication breakdowns leading to delays (Shantanu Nundy et al., 2008). In one study (Martin A. Makary et al., 2007) pre-briefing were associated with reducing OR staff perceived risk for wrong-site surgery and enhanced collaboration among OR staff.

The studies revealed that pre-briefings in the OR range from 2-minute to 10 minutes standardized discussions that included all surgical staff(Shantanu Nundy et al., 2008; Ali, Muhammad et al., 2011). These pre-briefing were often led by the attending surgeon. While a 2-minute or 10-minute pre-briefing may not be applicable for trauma care, one could argue that a 30-second to 1-minute pre-briefing can improve patient care, decrease flow disruptions, and reduce threats to patient safety as demonstrated in OR pre-briefing.

The pre-briefing identified in the studies aimed to familiarize the staff members with each other and operative plan before each surgical procedure. The specific content for the pre-briefing were designed based on non-structured observations (Yael Einav et al., 2010) and combined questionnaire and semi-structured focus group (Henrickson SE, et al. 2009). There was several outcome measurement tools used to access the impacts of pre-briefing. Those tools included the Safety Attitudes Questionnaire (SAQ) and the OR Briefings Assessment Tool (Martin A. Makary et al., 2007; Shantanu Nundy et al., 2008).

It is evident that pre-briefing is a reliable mechanism for safety improvement within the healthcare domain. Implementing an efficient and effective pre-briefing design for trauma care can prove to be valuable and could possibly render results similar to that in surgery.

Figure 11: Is there time to conduct a pre-briefing?



When we began implementation of the pre-briefing we found that the emergency department staff immediately embraced the idea. The surgical team, on the other hand, was concerned that there was not enough time to adequately complete a pre-briefing prior to the patient arrival. We went back to the pre-intervention data set and found that often there is very little time between trauma team activation and the arrival of the patient (figure 13). Since the trauma team members are scattered throughout the hospital, it takes time for them to assemble in the emergency department, reducing the time available for a pre-briefing. After several weeks of testing out a pre-briefing before traumas, and making a few tweaks to the process, all team members have embraced the idea. They have seen the value it brings to their process and pre-briefings have been adopted as standard practice with all trauma activations.

The surrogate measures we are observing include: was the pre-briefing completed before the patient arrived, was the whiteboard used in the pre-briefing, who led the brief, who participated in the brief, and what topics were covered in the brief? As mentioned previously, the surrogate measure data that we have collected to date will be summarized in the next section.

Intervention: **Data Dashboard / Smartphone Application**

The success of the whiteboard and the additional requirement to distribute and manage this information more effectively have lead to the development of an iPhone application to assist in the early management of trauma care. This has been designed to be easy to use, with minimal extra input required, while automatically distributing the vital data about the

incoming patient to the trauma team and to an electronic whiteboard. This allows the teams to begine preparations even before they arrive in the ED, which addresses the most pressing problem with the use of the whiteboard and the pre-briefing – that of sufficient time. This facility also allows a patient-oriented text and picture messaging function that will allow the distribution of communications and vital imagery to the care team. The application does not violate patient confidentiality, and is being carefully designed with direct user and human factors involvement, according to our primary principles of simplicity, communication, coordination and information management. While there are many medical applications available for smartphones, this is unique in offering a method to easily manage the process and information distribution for incoming trauma patients. This enhances the ability of the individual clinicians to apply the maximum wealth of their expertise to each case. A full trial version will be available imminently, and we believe offers a clinician-centered platform upon which a range of new and exciting capabilities can be built.

When a trauma is activated, the trauma team (consisting of trauma surgeons, respiratory therapists, emergency department nurses, emergency department physicians, pharmacists, imaging techs, etc) must all convene in the emergency department trauma bay. Since everyone arrives at different times due to their distance from the emergency department and what they were doing prior to the trauma activation (completing a surgery in the operating room, for example), having information available on the way could potentially expedite care. Receiving alerts on their phones, the entire trauma team can be on the same page when the patient arrives in the ambulance.

Figure 12: Wireframes of the Proposed Trauma App

Intervention: **Trauma Transport Medication Pack**

The team theorized that introducing a trauma transport medication pack will reduce patient-related flow disruptions. Many of the patient related flow disruptions involved patient movement within CT. If sedation medications were needed, the nurse or resident had to go back to the emergency department to retrieve the drugs. The guideline that was created is detailed below (figure 14).

Figure 13: Trauma Medication Travel Pack Guideline

1. *As part of transport preparation of intubated patients, sedation (and paralysis if indicated) is/are to be considered before movement from the ED. If no contraindications are present routine sedation and paralytic agents are to be provided prior to transport to prevent adverse events during transport.*
2. *The nurse and physician are to assess the likelihood of the patient awakening while in Imaging or arrival to the OR and ICU. This is of particular concern for Trauma patients who are intubated in the ED with the use of short-lasting RSI medications.*
3. *"ED Medication Travel Kit" is to be ordered by the physician and obtained by the nurse prior to patient transport if the patient:*
   a. *is at risk for early awakening from sedation and paralysis,*
   b. *is expected to be away from the ED for an extended period of time*
   c. *if a there exists a risk for prolonged transportation time*
4. *The **"ED Medication Travel Kit"** consists of two 2-mg vials (total of 4 mg) of midazolam (Versed®) and one 10-mg vial of pancuronium (Pavulon®).*
5. *Routine dosing of midazolam (0.03 – 0.1 mg/kg) and pancuronium (0.04-0.1 mg/kg) may be ordered by the treating physician(s) to manage the patient's needs for sedation and paralysis.*
6. *The **Adult Standard Dose** of 4 mg midazolam and 5 mg pancuronium is suggested to minimize errors in medication order communication and delivery.*
7. *Paralysis should not be provided without adequate sedation.*

As communication of the trauma pack occurred, the need for the trauma pack decreased. We observed that the team was doing a much a better job of addressing the patient's sedation needs prior to leaving the emergency department. Greater awareness has led to a better assessment of the stabilization, sedation, and analgesic needs of the patient prior to transport. We will continue to monitor the process and observe patient medication needs during transport.

Intervention: **Teamwork and Leadership Training**

Our focus on multi-dimensional interventions, and our discoveries concerning coordination and communication problems, led us to consider teamwork and leadership development. Two of our team members attended the TeamSTEPPS master trainer course at Duke University with the intent to incorporate the TeamSTEPPS material into our work. After taking the two-day course and hearing about the hurdles of physician adoption of TeamSTEPPS at Duke, the team spent a great deal of time with the training content in an attempt to streamline it. Taking a physician out of his or her clinic for two days to cover the full TeamSTEPPS course material is an unlikely scenario; our hypothesis is that the length of the course is why physician adoption has been slow at Duke. Rather than striving for amorphous, omnibus, culture-changing transformation as the initial goal, our approach will offer building blocks of skills, the accumulation of which can result in tangible improvements in team leadership.

The presenting evidence (disruption data, focus groups and observations) suggests a need for leaders to exhibit specific teamwork and communication skills. These skills may build a leader with stronger overarching leadership skills such as resiliency, emotional intelligence, business acumen, and so forth. The former is our target, while the latter is our hope. Small changes in daily behaviors/processes can, over time, result in changed attitudes.

By tightly focusing the training on the small, daily skills that are missing, undefined ("will we or will we not do a briefing?") or variable ("some chief Residents are great during the traumas, others not so much,") we arrived at training

that can be taught in 1-hour modules. With this granular approach, training will focus on specific, trainable, observable, relevant team and leadership skills. The specific topics we are targeting are: clear roles and responsibilities, dynamic and confident leadership, crisp communication, and managed conflicts. The training modules were delivered to two different test groups with two different configurations. The first group, the intensive training, received the four modules in two days. They received a two-hour dose on day one and a two-hour dose on day 2. The second group, the incremental training, received the four modules over the span of a month. They received a one-hour dose each week over a four week period. We hypothesized that the incremental group would produce better results since we would offer a small amount of material, allow them to try it out in practice for a week, and then return the following week to learn more. The intensive group, on the other hand, had to take in all of the material over a short span of time and implement all of the tools at once if they were going to incorporate them into their practice.

The specific training content that we developed for the physicians will be included in our final report. The survey results from the training are included in the next section.

Intervention: **Headsets**

The team theorized that implementing headsets will reduce communication and coordination flow disruptions. The headsets will allow information and decisions to be shared across the team. The trauma bay can be crowded and noisy with frequent distractions and interruptions. In addition, the frequent rotation of residents adds to the communication problems. Due to the critical nature of traumas, the headsets were tested in simulation in order to avoid any potential negative impact on a real trauma patient.

Two simulation sessions were conducted to test the use of headsets. During the simulations, the residents were asked to place a central line. The first simulations were conducted in quiet conditions, which we realized was not realistic and did not display any benefit to the headsets. In the second simulations, to make the scenario more realistic, the residents were given a detailed patient scenario, distracting patient care noises were played during the procedure, and multiple staged nursing interruptions were infused. All considered the second simulation to be extremely effective and engaging.

We measured time to complete the task, subjective workload using the NASA Task Load Index (TLX), and garnered subjective impressions of their use. Overall, with the small pilot simulations, the mean time to task completion was about 4% faster (6mins 28 seconds with vs 6 mins 44 seconds without), while the TLX was one point (<1%) higher. Overall, these was not enough to warrant further investigation of this technology. The surgeons liked that the headsets allowed for easier communication when people were not right next to each other. Additionally, the headsets provided good clarity in a chaotic environment. The surgeons did not like the size and weight of the headsets; they felt like the headset could slip off at any time. They also noted that it is difficult to focus on one person when so many voices are coming through the headset.

Aim 2, Task C: tests of change in simulation

We are currently in the process of finalizing the implementation of our proposed solutions and collecting data on the impact. A summary of the data that we have to date is included below.

Aim 2, Task D: successful interventions tested and refined at CSMC and partners

We are currently in the process of finalizing the implementation of our proposed solutions and collecting data on the impact. As mentioned previously, we collected specific measures on each intervention (surrogate measures) in conjunction with our overall flow disruption observations (outcomes measures). Below we have summarized the data that we have collected to date.

Intervention: **Whiteboard**

Since the Whiteboard has been implemented, it has been used in 68% (28 out of 41 cases) of trauma cases. There have only been 13 cases where the whiteboard was not used and in five of those cases, the patient arrived before the trauma team was activated. The buy-in from both the trauma surgeons and the emergency department staff has helped make the whiteboard an integral tool for this very fluid team.

Intervention: **Pre-Briefing**
Since the pre-briefing was implemented, it has been used in 41% (17 out of 41 cases) of trauma cases. The average time to conduct the pre-briefing is 38 seconds (maximum of 97 seconds and a minimum of 15 seconds). A very compact, focused pre-briefing within a very short amount of time was crucial in these often intense cases. On average, when a pre-briefing was completed, the team had an average of 11 minutes from the time the trauma pager was activated to when the patient arrived in the emergency department. In a large hospital, this does not give the team much time to get the emergency department and conduct the pre-briefing. Often the trauma team members are scrubbed into a surgery or rounding on patients in the ICU, which explains why the pre-briefing cannot always be completed.

When the pre-briefing did not occur (59% of the time, 24 out of 41 cases), the team simply did not have enough time to complete the process. In 5% of the cases where a pre-briefing did not occur, the patient arrived in the emergency department before the trauma team was activated. On average, when the pre-briefing was not completed, the team only had five minutes from the time the team was activated to when the patient arrived in the emergency department. One additional item of note, in 46% of the cases where a pre-briefing did not occur, a junior resident was the first trauma surgeon to arrive in the emergency department. While there may have been enough time to conduct the pre-briefing, the junior team member did not feel comfortable taking control of the room and running the pre-briefing.

A survey of 30 ED staff found that 83% agreed or agreed strongly that pre-briefing helped for coordinating trauma care, and the same proportion thought the information content was about right. 73% thought it was a good use of time, though only 63% though it should be lead by the trauma resident; those who disagreed instead suggested the nurse taking the EMC call should lead. Clearly reflected in the data is that only 46% of respondents agreed that there was enough time to conduct the briefing.

Intervention: **Lean Workspace Standardization**
In order to build in more time for the pre-briefing, the team wanted to reduce the amount of time needed to collect supplies before a trauma case arrived in the emergency department. Before the standardization commenced, we completed spaghetti maps for three different trauma scenarios and recorded both the time and distance needed to collect all of the supplies for that particular scenario. The three scenarios that were completed were: gunshot wound to the left chest with severe blood loss, left femur compound fracture with a stable patient and minimal blood loss, and finally, head trauma requiring intubation.

In the most acute scenario, the gunshot wound to the left chest, we were able to reduce the distance traveled to collect supplies by 12%. The time needed to collect those same supplies was reduced by 15%. In the femur and head trauma scenarios, we were able to reduce the time to collect supplies by 6% and 4% respectively.

Intervention: **Trauma Transport Medication Pack**
As communication of the trauma pack occurred, the need for the trauma pack decreased. We observed that the team was doing a much a better job of addressing the patient's sedation needs prior to leaving the emergency department. In the 41 cases that were observed, only 12% (5 cases) needed medications during transport to CT and in each one of those five cases, the drugs had already been retrieved and were with the team during transport. Greater situational awareness has led to a better assessment of the stabilization, sedation, and analgesic needs of the patient prior to transport.

Intervention: **Teamwork and Leadership Training**
Before and after the teamwork training, we administered surveys to assess both reactions to the training as well as assess learning. Additionally, the survey was administered to a control group of residents who did not receive the training.

The residents were asked four scenario based questions, which placed them in a difficult situation and asked for an assessment of how they would react in the situation. The survey results demonstrate that compared to the no-training control, responses to the post-intervention test were better for both intervention conditions; but and highest in the incremental condition. Additionally, teamwork attitudes were assessed. For example, residents were asked to assess the following statement on a five-point scale: it is not important for leaders to share information with team members. The results demonstrate that attitudes were highly positive compared to the control; and improved in the incremental condition but reduced slightly in the intensive condition. Finally, we assessed the overall reaction to the training: did they like it? While both groups had an overall positive reaction to the training, the incremental condition was more

popular than the intensive condition. Overall, the survey results all support the incremental training condition as the best method of delivery.

Both before and after the training was completed, a nurse in the ED observed the residents teamwork and leadership skills. We asked the nurse to note when she saw the TeamSTEPPS tools being utilized in the trauma bay. Before the training, the nurse noted 15 instances where she observed delegation, task assistance, read backs, and check backs. After the training was completed, she noted 383 instances of the TeamSTEPPS tools. Additionally, we asked the nurse to note observed leadership skills, specifically cooperation, communication, and situation monitoring. Before the training, she observed 184 instances of these specific leadership skills. After the training, she noted 690 instances of the same leadership skills. In both the intensive and incremental training groups, the residents immediately incorporated the leaning into their practice on the trauma team.

Intervention: **Headsets**
We are still in the process of assessing the data obtained during the headset simulation which includes flow disruptions, videos, audio, and the NASA task load index. We will have a more detailed analysis in our final report but have summarized the basic reaction data. During the simulation, the residents were asked to place a central line. To make the scenario more realistic, the residents were given a detailed patient scenario, distracting patient care noises were played during the procedure, and multiple staged nursing interruptions were infused.

The surgeons liked that the headsets allowed for easier communication when people were not right next to each other. Additionally, the headsets provided good clarity in a chaotic environment. The surgeons did not like the size and weight of the headsets; they felt like the headset could slip off at any time. They also noted that it is difficult to focus on one person when so many voices are coming through the headset.

We are nearing the end of our post-intervention data collection phase. While there is still a substantial amount of careful analysis to be performed, here we present an initial view of the outcome flow disruption data. Overall, we have studied 98 cases in the post-intervention period, of which 87 (88%) of cases were high level and 11 (12%) were lower level traumas. Six cases were OR cases. While this makes our post-intervention cases of slightly lower difficulty than the original sample, they are broadly comparable data sets. In the post intervention data period, the observers recorded 1033 flow disruptions, or a mean of 10.4 FDs per case. In contrast with the original data (20.4 FDs per case), this suggests that the flow disruption rate has nearly halved. Looking at the FD categories, most equipment, training and other FDs have stayed the same, while there are substantial reductions in communication, coordination, interruptions, environmental issues, and patient factors. This is precisely where we would have expected changes to occur based on the focus of our interventions. Though we must be initially cautious of these early results, they are as might have been predicted, and thus are extremely encouraging.

Aim 2, Task E: findings disseminated as best practices

We have not begun work on this step.

Key Research Accomplishments

- Developed an eRoom data sharing site that facilitates collaboration around the country
- Reviewed 32 trauma-related practice management guidelines and summarized them into five process maps
- Spoke to 73 people involved in the trauma process and summarized the findings into actionable output
- Visited Landstuhl Regional Medical Center and Madigan Army Medical Center to strengthen our military connection and ensure that our work will meet the needs of the military
- Trained medical students and PhD candidates in human factors and crew resource management methodologies to prepare them to identify flow disruptions during trauma cases
- Analyzed to an extraordinary degree the flow disruptions that occur during the course of nearly two hundred trauma cases in order to target our interventions to real-world problems in the trauma process
- Implemented six interventions to date. The initial surrogate measure data indicates that all six interventions have been successful
- Designed a streamlined version of the TeamSTEPPS course materials that is appealing to physicians.
- While there is still a substantial amount of careful analysis to be performed, the initial results from the post intervention data period show that the observers have seen 98 cases and recorded 1033 flow disruptions, or a

mean of 10.4 FDs per case. In contrast with the original data (20.4 FDs per case), this suggests that the flow disruption rate has nearly halved

We would like to note that our progress during the first year was significantly impacted by the delay in ORP HRPO approvals which is why we have requested a no cost extension in order to finalize our work. A complete timeline of the first year approval process is included in the appendix (Appendix Document 5: Protocol Approval History).

Reportable Outcomes

**see Appendix Document 6: Reportable Outcomes for the detailed academic output

Accepted Papers

Shouhed D, Wiegmann D, Gewertz B, Catchpole K (In Press). Integrating Human Factors Research and Surgery: A Review. Archives of Surgery.

Catchpole K, Wiegmann D (2012). Understanding safety and performance in the cardiac operating room: from 'sharp end' to 'blunt end'. BMJ Quality and Safety 21(10), 807-809.

Submitted Papers

Ley E, Wiegmann D, Blaha J, Blocker R, Shouhed D, Gangi A, Starnes B, Rush R, Taggart B, Karl C, Karl R, Gewertz B, Catchpole K. Characterizing Trauma Systems: Comparison of Methods for Identifying Improvements. Submitted to AAST.

Blocker, R, Shouhed, D, Gangi, A, Ley, E, Blaha, J, Gewertz, B, Wiegmann, D, Catchpole, K. Barriers to Efficient Trauma Care Associated with CT Scanning.
Submitted to JACS

Accepted Conference Abstracts

Shouhed D, Blocker R, Ley E, Blaha J, Gewertz B, Wiegmann D, Catchpole K. Flow Disruptions in CT. Western Surgical Association 2012 Annual Meeting

Blocker R, Duff S, Wiegmann D, Catchpole K, Blaha J, Shouhed D, Ley E, Karl C, Karl R, Gewertz B. Flow Disruptions in Trauma Surgery: Type, Impact and Affect. Human Factors and Ergonomics Society Annual Meeting 2012.

Catchpole K, Blocker R, Ley E, Gangi A, Blaha J, Gewertz B, Wiegmann D. Flow Disruptions in Trauma Care Handoffs. Academic Surgical Congress, 2013.

Gangi A, Catchpole K, Blocker R, Wiegmann D, Gewertz B, Blaha J, Ley E. Time To Prepare Impacts Emergency Department Efficiency And Flow Disruptions. Academic Surgical Congress, 2013.

Conference Presentations Completed

Shouhed D, Catchpole K, Ley E, Blaha J, Blocker R, Duff S, Karl C, Karl R, Gewertz B, Wiegmann D. Flow Disruptions in Trauma Care. American College of Surgeons 2012

Duff S, Wiegmann D, Blocker B, Catchpole K, Shouhed D, Ley E, Blaha J & Gewertz B. Transactive Memory Systems and Coordination in Trauma Care. 4th International Conference on Applied Human Factors and Ergonomics 2012.

Conference Posters Completed

Ley E, Catchpole K, Wiegmann D, Shouhed D, Blaha J, Blocker R, Duff S, Starnes B, Karl C, Karl R, Gewertz B. A Human Factors Approach to Flow Disruption in Civilian and Military Trauma Care. American Association for the Surgery of Trauma.

Duff S, Blocker R, Wiegmann D, Catchpole K, Shouhed D, Ley E, Blaha J, Gewertz B (2012). Transactive Memory Systems and Coordination in Trauma Care. Human Factors in Healthcare Symposium, Baltimore, 12-14 March 2012.

Catchpole K, Wiegmann D, Duff S, Blocker R, Shouhed D, Ley E, Blaha J, Gewertz B (2012). Observation of process, teamwork and error in surgery: A measurement framework. Human Factors in Healthcare Symposium, Baltimore, 12-14 March 2012.

Conclusion

The project is nearly complete. We have comprehensively studied the weaknesses of our current civilian trauma system using a bespoke PC-tablet and trained observers. We were able to analyze to an extraordinary degree the flow disruptions that occur during the course of nearly two hundred trauma cases. These data was used to develop a range of interventions focused on simplification, teamwork and communication, and information management, and then to re-evaluate the system following intervention. Training, whiteboard, pre-briefing and standardization interventions were all successful and popular. Headset simulation trials suggested that this was not yet a mature enough technology for further deployment. Ongoing work with an information, patient and process management smartphone application will be complete soon, with a range of exciting possibilities for the future. This project has demonstrated that detailed systems analysis, coupled with integrated, multi-dimensional interventions developed by clinicians and human scientists working in partnership can substantially improve the quality, efficiency and safety of care along the trauma pathway.

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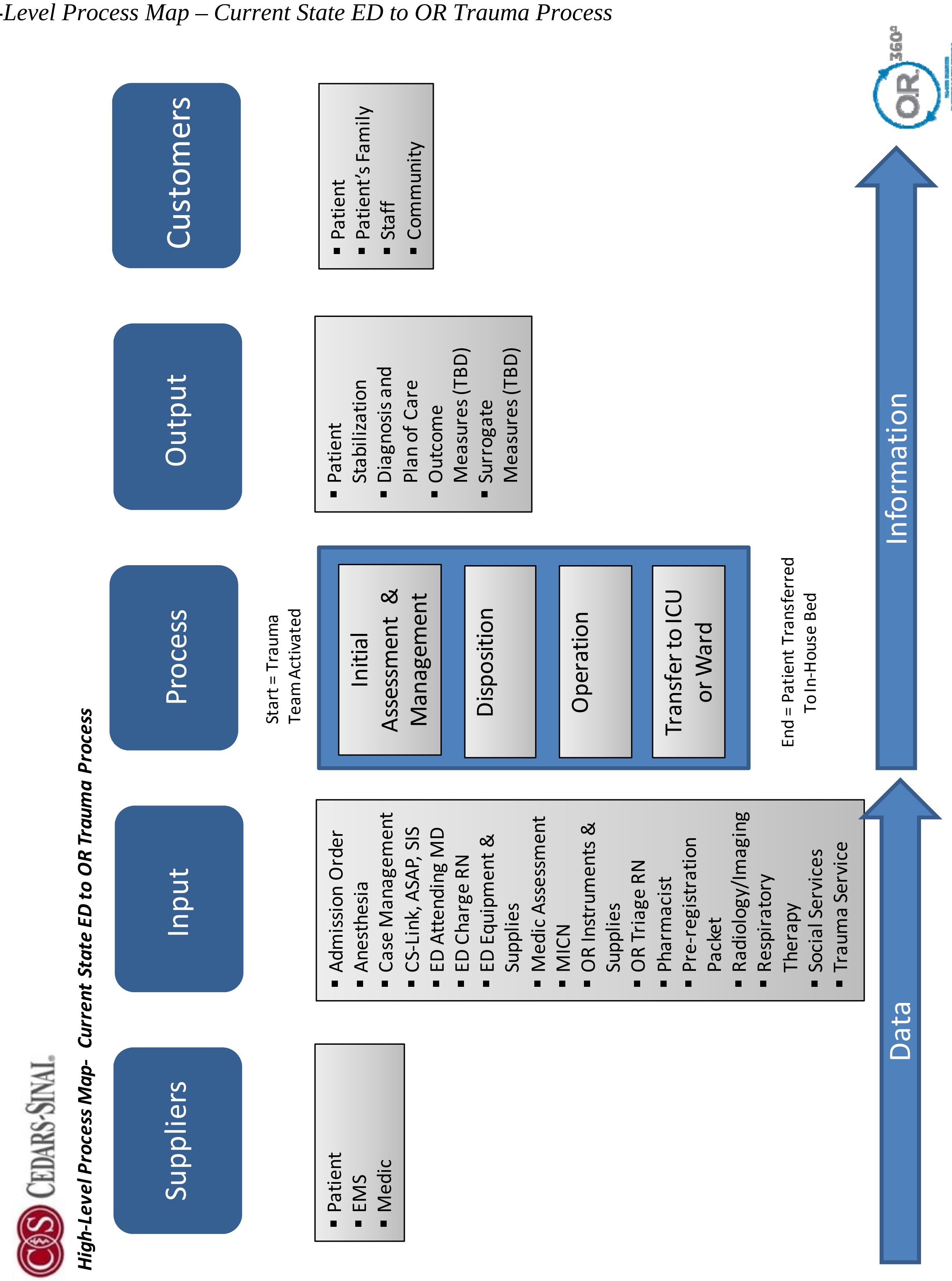
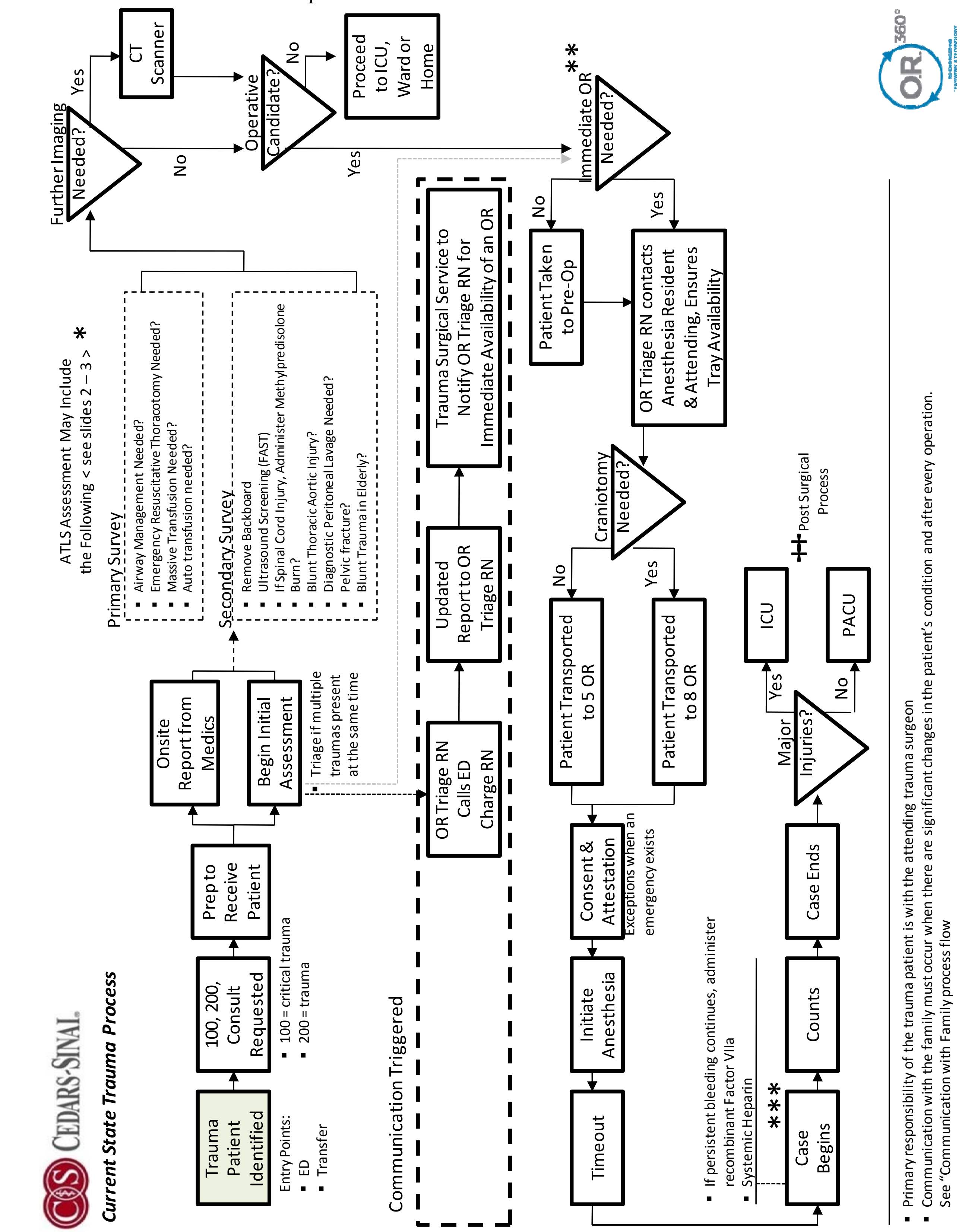
Appendices

Appendix Document 1: Process Maps

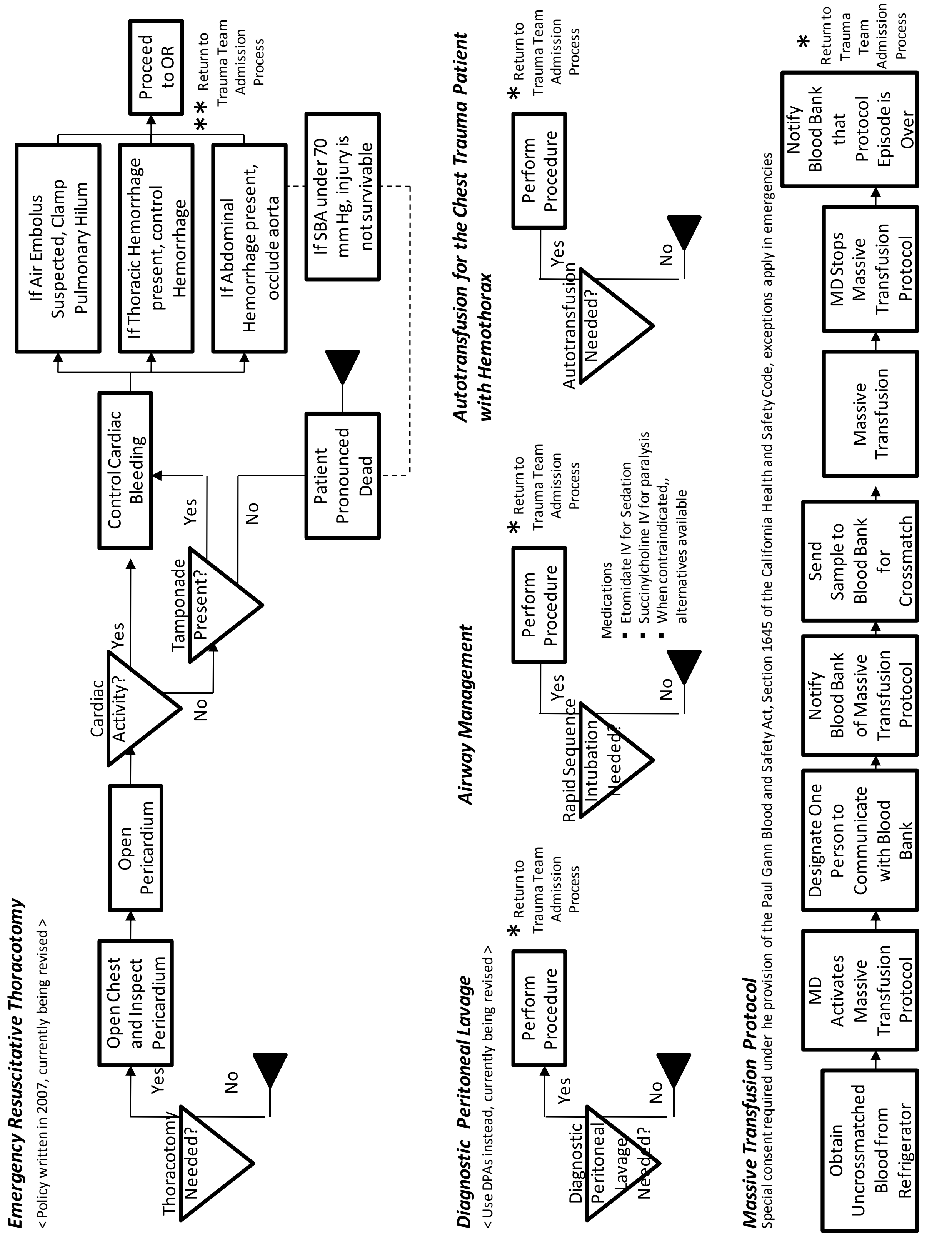
High-Level Process Map – Current State ED to OR Trauma Process



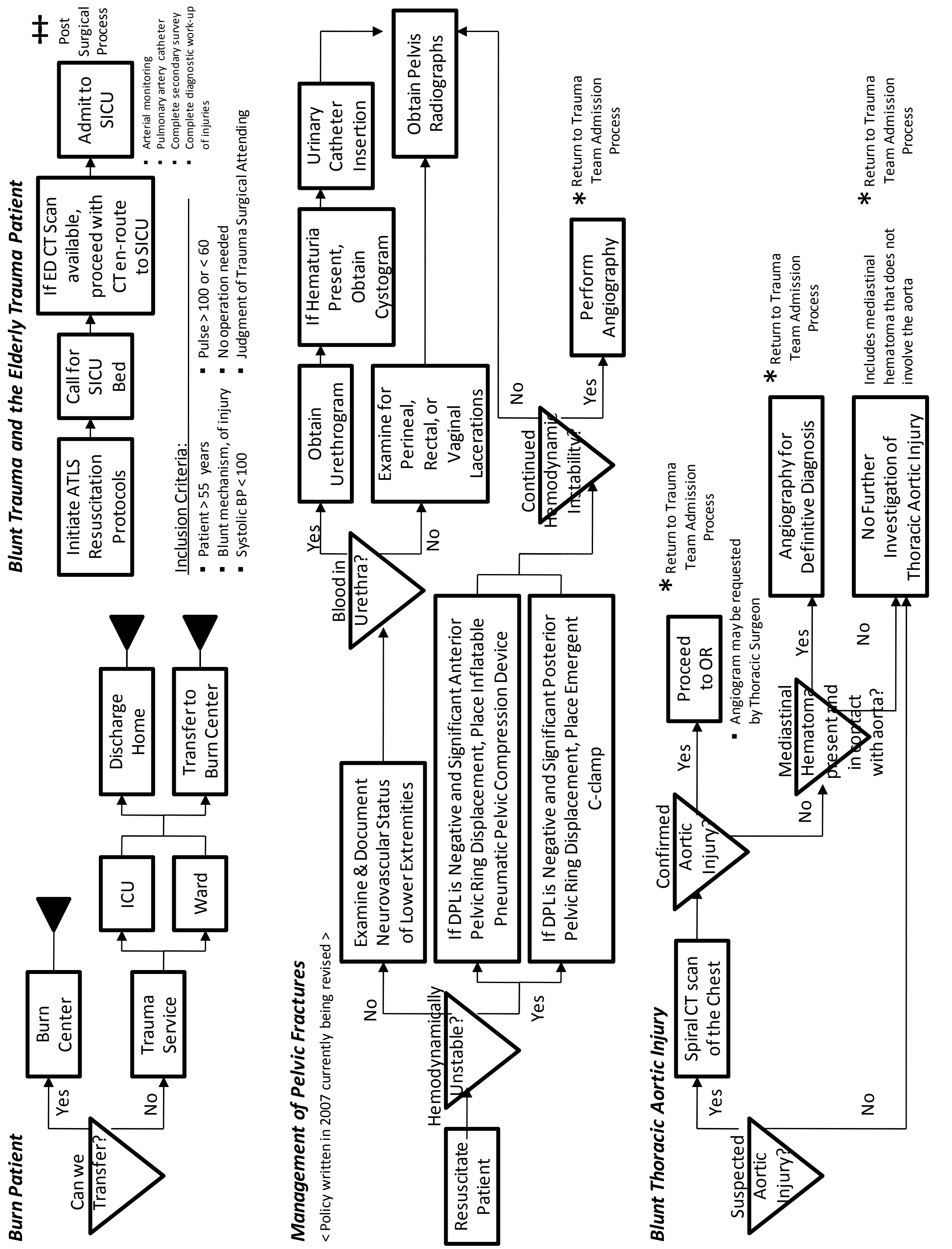
Current State Trauma Process Map



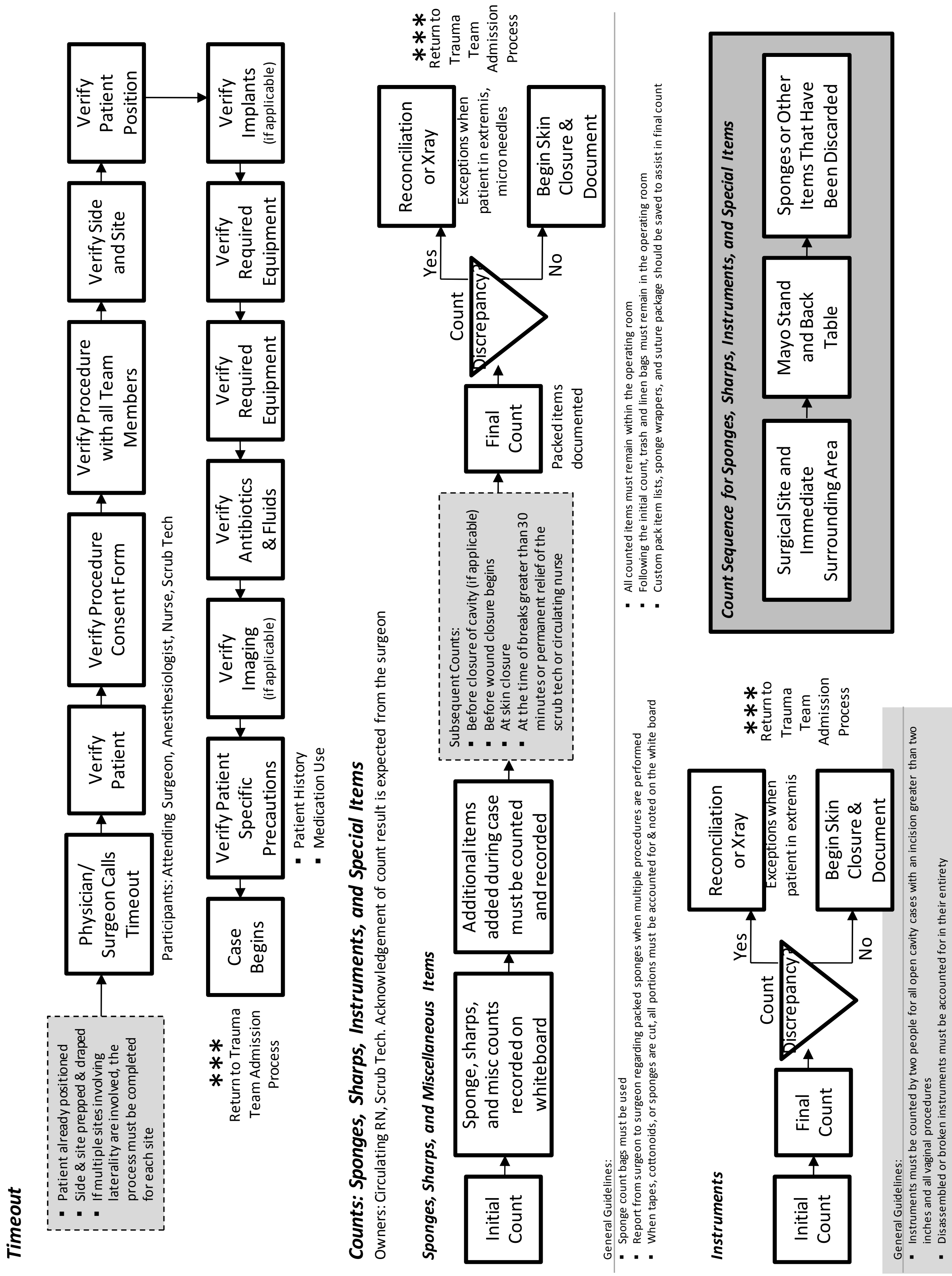
Primary and Secondary Survey Processes



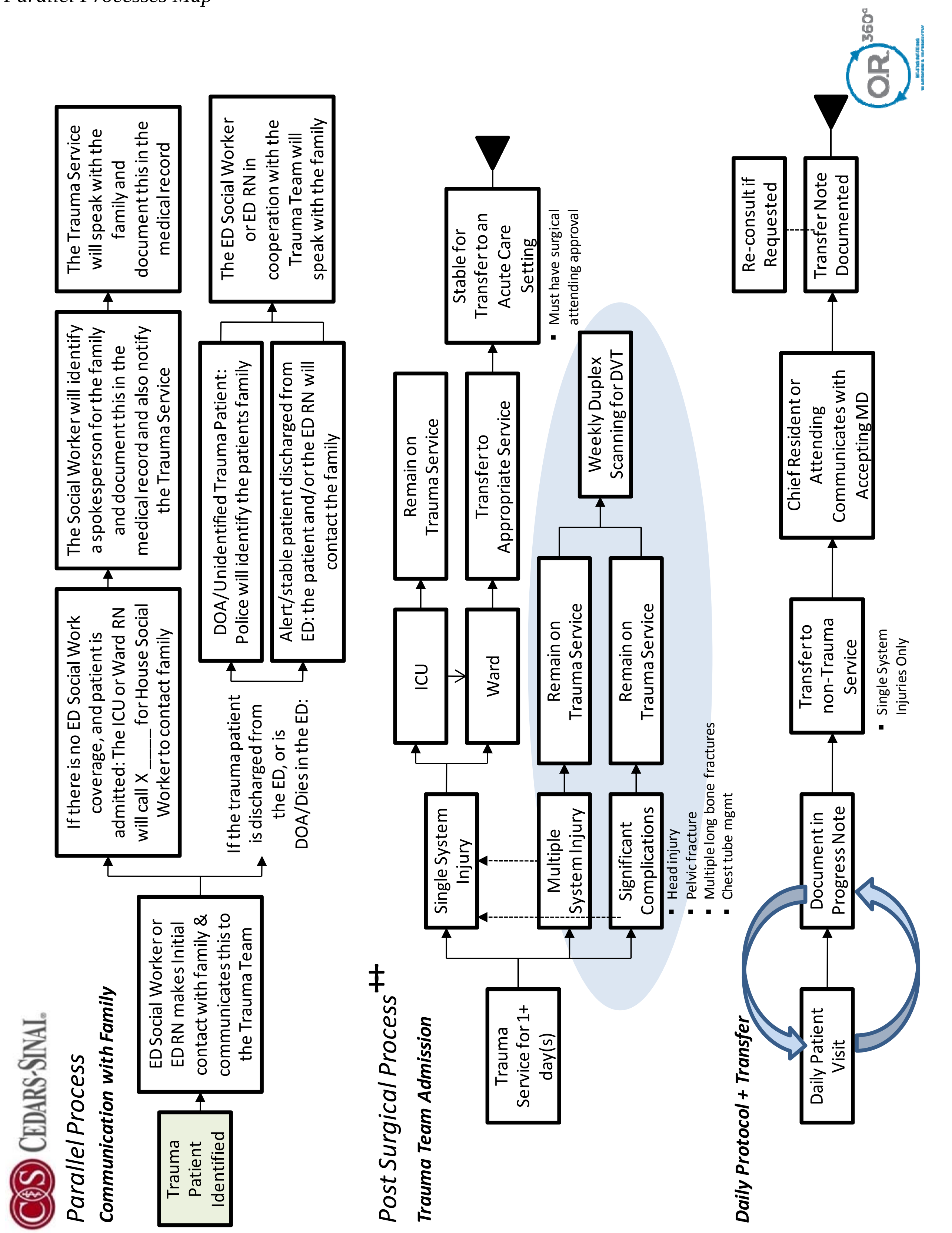
Primary and Secondary Survey Processes (2)



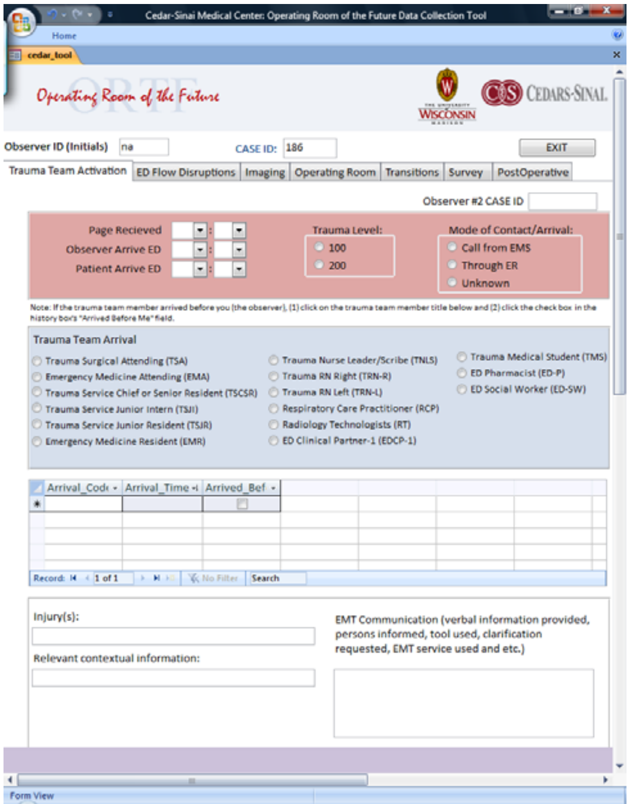
Timeout and Count Map



Parallel Processes Map



Appendix Document 2: Tablet PC Data Collection Tool Screen Shots



Appendix Document 3: Trauma Activation Criteria

"**Critical Trauma Activation**" (or 100) criteria:

1. Adults who sustained trauma with a systolic blood pressure of < 90 mmHg
2. Children (under 15 years old) with trauma and SBP < 70
3. Respiratory compromise and/or intubated (in the field)
4. Gunshot wounds to the neck, chest or torso
5. Stab wound with hypotension
6. GCS < 8 PLUS a significant traumatic mechanism of injury
7. Transfer of a trauma patient from another facility (ED to ED), who has received blood
8. Discretion of the Emergency Medicine physician, MICN, or ED Charge Nurse

"**Trauma Activation**" (or 200) criteria:

1. Spinal injury as evidenced by paralysis or loss of sensation
2. Diffuse abdominal tenderness and a mechanism of trauma
3. Amputation proximal to wrist and ankle
4. 2^{nd} or 3^{rd} degree burns > 20 % TBSA
5. GSW to extremity with loss of pulses, or diminished pulses.
6. Blunt injury to chest with unstable chest wall (flail chest)
7. Abnormal capillary refill and a mechanism of trauma
8. Blunt head injury associated with altered consciousness (GCS ≤ 12, excluding patients less than 1 year old), and has one or more of the following: seizures, focal neurological deficit (e.g., unequal pupils, hemiparesis)
9. Two or more proximal long bone fractures
10. All penetrating injuries to the head, neck, torso, and extremities proximal to elbow and knee
11. Auto-pedestrian or auto-bicycle injury with significant (>5mph) impact
12. Falls from heights > 15 feet
13. Surviving victims of vehicular accidents in which fatalities have occurred
14. Patients requiring extrication s/p auto crash
15. Rollover
16. High speed auto crash: initial speed > 40 mph, major auto deformity

20'', intrusion into passenger compartment > 12''

18. Patients ejected from a vehicle.
19. Motorcycle crash >20 mph with separation of rider from bike.
20. Any trauma patients age <5 or >55; history of cardiac or respiratory disease, insulin dependent diabetes, cirrhosis, morbid obesity or pregnancy.
21. Other trauma patients at the discretion of the Emergency Medicine Attending

Appendix Document 4: Quality Flow Disruption Analysis for RCA – Subcategory Details

Flow Disruption Categories	Count of FDs	%
Communication	367	24%
Workspace	307	20%
Coordination	264	17%
External Interruption	248	16%
Patient Factors	156	10%
In CT	121	8%
Getting to CT	82	5%
Total	1545	
Not a flow disruption	352	

Patient Factors	Count of FDs	%
Patient Uncooperative	54	35%
Moving during imaging	34	22%
Agitated or Upset	34	22%
In Pain	22	14%
Questions	9	6%
Difficult to move	3	2%
Total	156	100%

Communication	Count of FDs	%
Transfer of information	122	33%
Volume of people, noise	51	14%
Extraneous conversations	47	13%
Repeat	34	9%
Teamwork issues	30	8%
Verification	19	5%
Handoff	15	4%
Roles	15	4%
Unclear next steps	13	4%
Patient	10	3%
Timeout	6	2%
Counts	5	1%
Total	367	100%

Coordination	Count of FDs	%
Training	81	31%
Specialist	65	25%
Positioning	33	13%
Blood	19	7%
Interpreter	14	5%
Medication	13	5%
Orders	12	5%
ICU	9	3%
OR	8	3%
Lab	6	2%
Social Worker	4	2%
Total	264	100%

Getting to CT	Count of FDs	%
Scanner not available	37	45%
Monitors / Tubes	14	17%
Orders	12	15%
Transport	11	13%
Unclear next steps	8	10%
Total	82	100%

In CT	Count of FDs	%
Positioning	29	24%
Orders	23	19%
Volume of people, noise	23	19%
Monitors / Tubes	17	14%
Paperwork	8	7%
Training	7	6%
Patient Prep	6	5%
Medication	5	4%
Procedure in CT	3	2%
Total	121	100%

Workspace	Count of FDs	%
Equipment / Supplies	224	73%
Paperwork	26	8%
Monitors / Tubes	22	7%
Medication	17	6%
Patient blood	14	5%
Volume of people, noise	4	1%
Total	307	100%

External Interruptions	Count of FDs	%
Phone call	139	56%
Another patient	62	25%
Alarm	13	5%
Police questioning	10	4%
Room door	10	4%
Family	8	3%
EMT	6	2%
Total	248	100%

Appendix Document 5: Protocol Approval History

Protocol 1: Database Review (*16 weeks from submission to approval)*

Process Step	Date
Cedars-Sinai IRB approval	
Submission of protocol to Brigit Ciccarello	
Brigit Ciccarello requested additional documentation and then forwarded the protocol to Brian Garland	October 21, 2010
Additional information requested from Diana Weld	January 14, 2011
Cedars responded with additional information	January 18, 2011
Additional information requested from Diana Weld	January 25, 2011
Cedars responded with additional information	February 1, 2011
Final approval received from HRPO	February 14, 2011

Protocol 2: Focus Groups (*7 weeks from submission to approval)*

Process Step	Date
Cedars-Sinai IRB approval	March 16, 2011
Submission of protocol to Brigit Ciccarello	March 21, 2011
Brigit Ciccarello requested additional documentation and then forwarded the protocol to Brian Garland	March 23, 2011
Additional information requested from Diana Weld	March 28, 2011
Cedars responded with additional information	March 29, 2011
Final approval received from HRPO	May 4, 2011

Protocol 3: Observations (*11 weeks from submission to approval)*

Process Step	Date
Cedars-Sinai IRB approval	June 3, 2011
Submission of protocol to Brigit Ciccarello	June 9, 2011
Brigit Ciccarello requested additional documentation and then forwarded the protocol to Brian Garland	June 13, 2011
Additional information requested from Diana Weld	July 21, 2011
Cedars responded with additional information	July 26, 2011
Final approval received from HRPO	August 28, 2011

Appendix Document 6: Reportable Outcomes *All papers & abstracts are included in this section of the appendix.*

Accepted Papers

Shouhed D, Wiegmann D, Gewertz B, Catchpole K (In Press). Integrating Human Factors Research and Surgery: A Review. Archives of Surgery.

Catchpole K, Wiegmann D (2012). Understanding safety and performance in the cardiac operating room: from 'sharp end' to 'blunt end'. BMJ Quality and Safety 21(10), 807-809.

Submitted Papers

Ley E, Wiegmann D, Blaha J, Blocker R, Shouhed D, Gangi A, Starnes B, Rush R, Taggart B, Karl C, Karl R, Gewertz B, Catchpole K. Characterizing Trauma Systems: Comparison of Methods for Identifying Improvements. Submitted to AAST.

Blocker, R, Shouhed, D, Gangi, A, Ley, E, Blaha, J, Gewertz, B, Wiegmann, D, Catchpole, K. Barriers to Efficient Trauma Care Associated with CT Scanning.
Submitted to JACS

Accepted Conference Abstracts

Shouhed D, Blocker R, Ley E, Blaha J, Gewertz B, Wiegmann D, Catchpole K. Flow Disruptions in CT. Western Surgical Association 2012 Annual Meeting

Blocker R, Duff S, Wiegmann D, Catchpole K, Shouhed D, Ley E, Karl C, Karl R, Gewertz B. Flow Disruptions in Trauma Surgery: Type, Impact & Affect. Human Factors and Ergonomics Society Annual Meeting 2012.

Catchpole K, Blocker R, Ley E, Gangi A, Blaha J, Gewertz B, Wiegmann D. Flow Disruptions in Trauma Care Handoffs. Academic Surgical Congress, 2013.

Gangi A, Catchpole K, Blocker R, Wiegmann D, Gewertz B, Blaha J, Ley E. Time To Prepare Impacts Emergency Department Efficiency And Flow Disruptions. Academic Surgical Congress, 2013.

Conference Presentations Completed

Shouhed D, Catchpole K, Ley E, Blaha J, Blocker R, Duff S, Karl C, Karl R, Gewertz B, Wiegmann D. Flow Disruptions in Trauma Care. American College of Surgeons 2012

Duff S, Wiegmann D, Blocker B, Catchpole K, Shouhed D, Ley E, Blaha J & Gewertz B. Transactive Memory Systems and Coordination in Trauma Care. 4th International Conference on Applied Human Factors and Ergonomics 2012.

Conference Posters Completed

Ley E, Catchpole K, Wiegmann D, Shouhed D, Blaha J, Blocker R, Duff S, Starnes B, Karl C, Karl R, Gewertz B. A Human Factors Approach to Flow Disruption in Civilian and Military Trauma Care. American Association for the Surgery of Trauma.

Duff S, Blocker R, Wiegmann D, Catchpole K, Shouhed D, Ley E, Blaha J, Gewertz B (2012). Transactive Memory Systems and Coordination in Trauma Care. Human Factors in Healthcare Symposium, Baltimore, 12-14 March 2012.

Catchpole K, Wiegmann D, Duff S, Blocker R, Shouhed D, Ley E, Blaha J, Gewertz B (2012). Observation of process, teamwork and error in surgery: A measurement framework. Human Factors in Healthcare Symposium, Baltimore, 12-14 March 2012.

INTEGRATING HUMAN FACTORS RESEARCH AND SURGERY: A REVIEW

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ABSTRACT:

Objective: To provide a review of human factors research within the context of surgery.

Data Sources: We searched PubMed for relevant studies published from the earliest available date through February 29, 2012.

Study Selection: The search was performed using the keywords “human factors,” surgery, errors, teamwork, communication, stress, disruptions, interventions, checklists, briefings and training. Additional articles were identified by a manual search of the references from the key articles. The authors—two human factors specialists, a senior clinician and a junior clinician—carefully selected the most appropriate exemplars of research findings with specific relevance to surgical error and safety.

Data Extraction: 77 papers of relevance were selected and reviewed in detail. Opinion pieces were disregarded with a focus solely on articles based on empirical evidence, with a particular emphasis on prospectively designed studies.

Data Synthesis: The themes that emerged related to the development of human factors theories; the application of those theories within surgery; a specific interest in the concept of “flow”; and the theoretical basis and value of human-related interventions for improving safety and flow in surgery.

Conclusions: Despite increased awareness of safety, errors routinely continue to occur in surgical care. Disruptions in the flow of an operation, such as teamwork and communication failures, contribute significantly to such adverse events. While it is apparent that some incidence of human error is unavoidable, there is much evidence in medicine and other fields that systems can be better designed to prevent or detect errors before a patient is harmed. The complexity of factors leading to surgical errors requires collaborations between surgeons and human factors experts to carry out the proper prospective and observational studies. Only when we are guided by this valid and "real world" data can useful interventions be identified and implemented.

INTRODUCTION

While the precise incidence and epidemiology of "medical mistakes" still elicits debate, all can agree that human errors are inevitable in any endeavor. Errors typically have little to no consequence and often go unnoticed, but occasionally they translate into an adverse event. In the medical setting, this may be reflected in prolonged hospital stays, morbidities, or mortalities.[1–3] A growing consensus acknowledges that while errors and adverse events are often committed by individuals, they are by and large the product of faulty systems and inadequate organizational structure set forth by the institution.[4–6] Because of the critical nature of many operative interventions, surgery accounts for a large number of medical errors. In one retrospective review conducted by Gawande et al., 66% of all adverse events were found to be surgical in nature, most of which occurred in the operating room; 54% of these were judged to be preventable.[1,7] Beyond their cost in human lives, preventable medical errors result in financial costs projected to be between $17 billion and $29 billion per year in US hospitals.[8]

Human factors engineers seek to identify the root causes of medical and surgical errors within vulnerable systems with the intent of optimizing performance.[9] Human factors research can provide a pragmatic framework for analyzing and assessing risk and reducing error by considering where system designs could take better account of human capabilities and fallibilities. In this paper, we will review 1) the systematic nature of errors and how they relate to the field of surgery, 2) human factors studies within the practice of surgery, and 3) the most promising interventions that have been implemented to date.

METHODS

The authors searched PubMed for relevant studies published from the earliest available date through February 28, 2012. The search was performed using the keywords "human factors," surgery, errors, teamwork, communication, stress, disruptions, interventions, checklists, briefings, and training. The breadth of the topic and methodological and theoretical diversity of human factors research meant that a systematic review was neither possible nor desirable. Instead, the authors – two human factors specialists, a senior clinician and a junior clinician – carefully selected the most appropriate exemplars of research findings with specific relevance to surgical error and safety. Opinion pieces were disregarded with a focus solely on articles based on empirical evidence, with a particular emphasis on prospectively designed studies. 77

papers of relevance were selected and reviewed in detail. The themes that emerged related to the development of human factors theories; the application of those theories within surgery; a specific interest in the concept of "flow"; and the theoretical basis and value of human-related interventions for improving safety and flow in surgery.

HUMAN FACTORS AND SYSTEMS

Human factors can be described as "the study and design of environments and processes to ensure safer, more effective and more efficient use by humans."[10–12] The general objective of human factors engineers within the domain of healthcare is to maximize human performance and system efficiency, while promoting health, safety, comfort, and quality of life.[13,14] Adopting a systems approach to understanding surgical errors is based on three principles: 1) human error is unavoidable, as it is an inherent aspect of human behavior 2) defective systems allow human error to cause harm to the patient; 3) systems can be designed to prevent or detect human error before a patient is harmed.[15] According to this perspective, errors are the natural consequences, not the causes, of those systemic breakdowns that impact performance.[16]

Perhaps the most familiar human factors theory is the "Swiss Cheese" model of accident causation. This provides a theoretical framework for the etiology of errors within the context of systems (Figure 1). According to this model, accidents are a result of both *active* and *latent* failures. Active failures are unsafe acts committed by the people at the human-system interface whose actions can have immediate, adverse consequences. Latent failures are the result of poor systems design or decision-making by members of the organizational and management spheres. The damaging consequences of latent failures may lie dormant for a long time, only to become evident when they combine with active failures. Each slice of "cheese" is analogous to a systemic defense against error, and the holes within each slice are a combination of active and latent failures. Occasionally, the holes within each layer of defense will line up together, allowing an error to bypass the system's defenses and translate into an accident.[17–19]

Preventable adverse events are therefore not simply the result of human error, but rather are due to defective *systems* that allow errors to occur or go unnoticed.[15] The Systems Engineering Initiative in Patient Safety (SEIPS) model is a useful illustration of the components of a system (Figure 2). It places the individual at the center and carries the notion that all the elements of the system not only have an effect on the individual but also on the other elements

within the system. This model suggests that surgical skill, overall performance and outcomes are strongly impacted by such factors as teamwork and communication, the physical working environment, technology, workload factors and other organizational variables. In turn, the components of the system can influence each other.[20] For example, introduction of a new technology, such as a surgical robot, requires new skills to be learned, a suitable environment to operate and maintain it, and organizational support for the technology and people utilizing or being treated with the new technique.

HUMAN FACTORS IN SURGERY

There is a growing body of literature relating human factors science to the practice of surgery. Operating rooms (OR) are commonly intricate, high-stress environments occupied by a broad array of technological tools and interdisciplinary staff. The operating room has a unique set of team dynamics, as professionals from multiple specialties, whose goals and training differ widely, are required to work in a closely coordinated fashion.[21] This complex setting provides multiple opportunities for suboptimal communication, clashing motivations, and errors arising not from technical incompetence but from cognitive biases, poor interpersonal skills and substandard environmental factors.[21,22]

Environmental factors within the OR such as clutter, congestion, noise, lighting and temperature have been shown to negatively impact surgical performance.[23–25] Congestion due to the location of equipment and displays, as well as the disarray of wires, tubes and lines, known as the "spaghetti syndrome," is a common scenario in the operating room.[26] Consequently, movements by members of the surgical team are often obstructed, wiring is difficult to access and maintain, and the risk of accidental disconnection of devices and human error increases.[27]. Noise can hinder the ability of a surgeon to concentrate by masking acoustic cues and interfering with internal thought processes.[13] Excessive noise may also prevent critically relevant communications from occurring among team members.[28]

Poor communication has been increasingly regarded as causal factors in a large percentage of sentinel events within the healthcare system.[29–32] The Joint Commission reports communication as the number one root cause of sentinel events from 1995 through 2004. Incomplete or erroneous communication and indicated that such events were causal factors in 43% of errors made during surgery.[33] Yet another study found that 36% of communication

errors in the operating room resulted in inefficiency, team tension, resource waste, patient inconvenience and procedural error.[34] Surgeons who are capable of adapting their communication style when operating with new or inexperienced team members have been able to foster team coordination in a manner that reduces errors and improves patient outcomes.[35]

Similarly, technical surgical errors cannot be understood in isolation from the actions of other members of the team. In one study teamwork factors alone accounted for 45% of the variance in the errors committed by surgeons during cardiac cases.[31] In a study comparing the effectiveness of primary (familiar) and secondary (unfamiliar) surgical teams, primary teams revealed significantly fewer surgical errors and miscommunication events per case.[16] The stability of a cohesive team fosters the development of trust among team members, which allows for adaptation to non-verbal communication styles and facilitates the anticipation of others' actions.

Although effective teamwork and communication are fundamental to patient safety in the operating room, acute stress increasingly is recognized as a key component of surgical performance.[36,37] Surgeons encounter frequent stressors in the operating room, including technical complications, time pressure, distractions, interruptions and increased workload.[38] Excessive levels of intra-operative stress can compromise both technical and non-technical skills.[39,40] Indeed, being able to operate effectively under such stress-inducing conditions is a hallmark of expertise.[38] A marker of surgical excellence is not "error free" performance but rather the ability to manage errors and problematic events during an operation.[41] In essence, since patient anatomy and physiological response to surgery may not always be predictable, it makes sense to control for as many other uncertainties as possible, and thus allow a more appropriate individualized response for each patient. This may ultimately illustrate the need for surgery-specific human factors theoretical development, as aviation models, for example, become increasingly outdated.

PROSPECTIVE ANALYSIS OF FLOW DISRUPTIONS

Methods of capturing systemic errors include both retrospective reviews and prospective observational studies. Retrospective studies are prone to hindsight bias.[42] For example, it is difficult to determine how sleeplessness, distractions, poor communication, and technical factors may have contributed to the occurrence of a retained sponge in the abdomen weeks after the

event transpired. Additionally, retrospective studies cannot detect near harm or potential adverse events, which occur far more frequently and offer as much information as the catastrophic but rare adverse event.[43–45] In contrast, prospective observational research offers objective analysis of events and allows for the study of near-misses, errors, adverse events, team performance, and organizational culture.[46,47] However, the rarity of capturing an uncommon death or adverse event makes it difficult to justify endless hours of observation. This dilemma has prompted researchers to monitor the quality of performance through the measurement of outcome events other than death.[48] Surrogate measures, such as errors and disruptions, can often be used to predict the occurrence of a catastrophic adverse event or death if the proposed measure correlates with a clinically meaningful outcome and fully captures the effect of a particular treatment.[49]

The concept of "flow" was first promulgated in the 1960's by Mihaly Csikszentmihalyi when he observed artists who would get lost in their work, disregarding their need for food, water, and even sleep. Flow is a mental state in which a person is fully immersed in a complex activity that is intrinsically motivated by his/her own talents and interests; flow imparts a distorted sense of time and a loss of any feeling of self-consciousness. According to Csikszentmihalyi, flow can only be attained if an individual possesses the proper skill set necessary to carry out a task worthy of the challenge. While flow shares some surface characteristics with other urgent tasks, it is elevated by the matching of hard-won skills and innate talents with a meaningful and noble purpose.[50,51] When this concept is applied to the field of surgery, flow could refer to the ease and fluidity with which an operation progresses.

Surgical flow disruptions .are deviations from the natural progression of a procedure which potentially compromise the safety of the operation.[31] The significance of flow disruptions lies in their ability to provide a window on the quality and safety of the system before a serious accident occurs.[42] Indeed, flow disruptions can be viewed as a surrogate measure for errors occurring in the operating room. Although a single flow disruption will likely result in little to no consequence on the outcome of an operation, the accumulation of flow disruptions has empirically been linked to a higher prevalence of surgical errors.[31] Observational studies focusing on flow disruptions allow for a systematic, quantitative and replicable assessment of the relations between the surgical environment, processes and outcomes.[52]

Through the observation of 31 cardiac surgery operations, Wiegmann and colleagues showed that surgical errors increase significantly with increases in flow disruptions such as

impaired teamwork, communication failures, equipment and technology problems, extraneous interruptions and issues in resource accessibility.[31] Catchpole et al. confirmed that complications during operations can arise from an escalation of smaller problems and that these problems can be mitigated by effective teamwork and communication.[21,53] de Leval et al. prospectively observed 243 arterial switch operations among pediatric patients in 16 British institutions and analyzed the effects of major and minor events. They found that both major events (those errors which are likely to have direct and serious consequences to the patient) and the accumulation of minor events (those which disrupt the smooth flow of the procedure) had significant effects on death and/or near misses.[6] They also found that as the number of minor events increased, the ability of a surgical team to cope with major problems significantly decreased.[54] They concluded that the accumulation of minor events appeared to diminish the compensatory resources of the surgical team, increasing their susceptibility to committing errors.[35]

In another prospective ethnographic study, communication breakdown and information loss, as well as increased workload and competing tasks, were found to pose the greatest threats to patient safety in the operating room.[12] Sevdalis et al. found that distractions and interruptions related to communication, equipment, procedures, and the operative environment occurred most frequently and were most visibly disruptive.[55] They also found the most distracting communications to be related to operating room equipment, responses to queries about other patients, and on-going management of the operating list with the members of the operating room team.[56] Similar patterns have been obtained in urological surgery as well as specialties outside surgery, including intensive care units and emergency departments.[57–60]

INTERVENTIONS

The analysis of errors and adverse events in healthcare has prompted the implementation of several types of interventions to help reduce the frequency of such events. Checklists, most notably the WHO Surgical Safety Checklist, have been proposed to improve safety and process reliability. Checklists ensure against errors of omission, promote explicit consistency of repetitive tasks, and improve procedural learning as well as process reliability.[18] However, a checklist will only be effective if it is well designed and used appropriately; as a consequence not all checklist studies show efficacy.[61,62] When such interventions do not complement existing systems of work, they may be met with cultural resistance, particularly when they are viewed as

just another task to complete.[63,64] Despite the adoption of a surgical site marking checklist mandated by the Joint Commission on Accreditation of Healthcare Organization in 2004, wrong site surgeries and near misses continue at an unchanged pace.[65]

Another potential solution to improving safety and efficiency in the operating room is the pre-operative briefing. Briefings improve team awareness or knowledge through shared information, explicit confirmation, reminders or education. They also help identify problems, encourage prompt decision-making and initiate follow-up actions.[32] Briefings have been found to significantly reduce the perceived risk for wrong-site surgery and improve perceived collaboration among the operating room staff.[66,67] They have also been found to reduce communication failures, reduce disruptions in surgical flow, reduce delays and allow better identification of problems and knowledge gaps.[32,68,69] Despite the benefits that they provide, briefings may be viewed negatively by some because of associated delays and the need to simultaneously assemble all members of the operating team.

A third solution which has become increasingly popular is the implementation of teamwork-based training courses. These courses aim to improve interpersonal relationships through the improvement of non-technical skills such as communication and leadership. They have been shown to deliver better observed team skills, better satisfaction with care, improved compliance with briefings and reduced error rates.[70–75] They can also lead to better organizational perceptions that help sustain institutional change.[72,76,77] Improved teamwork ultimately leads to intersecting goals among team members, thereby improving the flow with which an operation progresses. However, such training largely derives from aviation principles which may not always apply to the specific needs of the teams, and in most cases, the requirements for refresher training are poorly considered. The complexity of patient physiology requires that a physician approach the human body as an inter-related system composed of multiple organs constantly communicating and interacting with one another. Pathologic conditions are rarely corrected by a "silver bullet" approach, but rather require multimodal treatments. The systemic failures within healthcare, which lead to errors and adverse events, may also need to be remediated in a similar manner. Checklists, briefings and teamwork training can all be effective in reducing systemic failures; however, there are many more opportunities to improve flow. In fact, the SEIPS and other human factors models suggest that training and behavioral change should be seen as a last resort. Improving the design of

equipment, the order, allocation and definition of surgical tasks, the design of the surgical environment, and the organization of services and support around the maintenance and improvement of surgical flow could all yield improvements in surgical performance and eventually outcomes. Therefore, the best approach to improving safety is likely to be a combination of approaches.

CONCLUSION

Although most recommendations for surgical improvement would be to carefully implement checklists, briefings and training, organizational leaders must consider the effects such changes will have on the system as a whole. In order to improve working environments for the whole team and sustain positive systemic changes, one must fully understand the violations and why individuals and organizations drift away from safety. The continuation of prospectively designed studies through direct observation of flow disruptions, coupled with incident reporting systems, and the utilization of the morbidity and mortality conferences will help us to understand why errors occur, and thus develop the best solutions for change.

While it is apparent that some incidence of human error is unavoidable, there is much evidence in medicine and other fields that systems can be better designed to prevent or detect errors before a patient is harmed. The complexity of factors leading to surgical errors requires collaborations between surgeons and human factors experts to carry out the proper prospective and observational studies. Only when we are guided by this valid and "real world" data can useful interventions be identified and implemented.

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Understanding safety and performance in the cardiac operating room: from 'sharp end' to 'blunt end'

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Successful surgery requires a patient with an accurate diagnosis, a treatment plan with an acceptable chance of success, a skilled surgeon and supporting team, a range of equipment, drugs and disposable items to support complex surgical tasks, a follow-up care team to ensure appropriate postoperative recovery and discharge, and an organisation that supports the people and helps to coordinate the delivery of all aspects of care. The tragic consequences that can ensue from failures across this broad range of system components came to light in the case of paediatric cardiac surgery some 15 years ago. Incidents in Winnipeg, Canada,[1] and Bristol, UK,[2] led to inquiries into surgical deaths that were among the first to highlight the complex range of systemic influences on surgical performance. These thorough analyses revealed a huge range of 'blunt end' system problems: surgical volumes, leadership and organisational issues, dysfunctional communication between teams and departments, and the basic predisposition to error imposed by the complex amalgam of team, task, process and technical ability within the surgery itself.

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Emerging partly from those events was perhaps the seminal observational multidisciplinary study in surgical care conducted by Carthey and de Leval *et al*.[3] They demonstrated that even successful operations were often fraught with large numbers of potential problems that arose as a result of systems issues. More importantly for outcomes-based research, they found that enough of these minor problems in one operation could contribute to increased morbidity and mortality.[4] Furthermore, the actions of the team in recovering from these problems could make the difference between a good and a poor outcome.[5] This study was therefore critical in making direct inferential links between surgical outcomes, human factors and systems issues.

Subsequent research developed these observational techniques and a suggested model for understanding error causation in surgery.[6] Videotaping operations produced transcripts of errors as they happened,[7] thus allowing identification of the mechanisms by which minor problems escalate into major ones,[8] and the influence of potentially trainable teamwork skills on that escalation. These findings were replicated and further developed in a later set of studies in identical surgeries in The Netherlands,[9 10] as well as being extended into other surgical domains.[11 12]

At about the same time, similar results were also being reported in adult cardiac surgery, again employing direct observation by multidisciplinary teams consisting of clinicians and human factors professionals. In a sequence of studies at the Mayo Clinic, Wiegmann and colleagues identified similar minor problems, which they usefully called flow disruptions. It was possible to relate these directly to surgical errors.[13] This work also began to refine the observational methods required to obtain this type of information reliably,[14] examining the practical constraints of observation in surgery and moving from the unstructured note-taking and checklists of the early observations to more structured data collection. Other groups were also developing and deploying direct observational methods to understand teamwork and process across a variety of procedures demonstrating a range of causes of turbulence in surgery.[15 16] The underlying principle that was being developed and expounded through 'sharp end' observational studies was that the influences on surgical performance and outcome went well beyond simply the skills of the surgeon or the wellness of the patient, even for successful operations.

One common feature of all this work was the close interrelationship between teamwork, technology and task in surgical success and failure,[7] confirming the view that it is the people that held together the otherwise unsafe system, and that human errors and systems problems were frequent.[17] This led naturally to experiments with team-based interventions, such as training,[18 19] checklists[20 21] and briefings.[22] A subsequent challenge was then to identify higher-order sources of hazards in the operating environment that might lead to solutions that go beyond training or teamwork. Various methods have been offered to structure the analysis of behavioural observations to assist in the identification and correction not just of hazardous behaviours at the 'sharp

end,'[23] but of latent systems problems (at the 'blunt end') that were causing those hazards.[24–26]

The research presented by Gurses *et al*[27] in this issue is perhaps the next phase in that evolution of understanding through direct observation and analysis of work processes. As with previous studies, their research seeks to look deeper into the systems of care in cardiac surgery. Their special contribution to this body of literature is that they do not focus directly on teamwork or task-related behaviour, but rather on the predisposition to error through equipment, environmental, workspace and organisational factors, which they identify through physical and behavioural artifacts within the operating rooms they visited. This is particularly valuable where, for example, traditional methods focus on the design of one piece of equipment in isolation, without effectively taking into account interactions between them. Thus, it opens up the possibility of a deeper systems analysis and the generation of a wider range of solutions to safety and quality problems.

Though extremely broad-ranging and time-intensive (and thus costly) to conduct, such behaviourally oriented, richly representational, direct observations analyse work 'as performed' rather than 'as imagined'. The observations and analyses tell us what really happens rather than what we might speculate happens or what 'should' happen. This methodology not only provides the keenest context specificity and face validity, but also generates data with richness of detail not available by any other means. Incident reporting, for example, not only notoriously under-captures events of interest,[28] but also tends to lack many contextual details that can prove to be important in understanding safety.

The ability to provide a detailed understanding of 'normal' systems state is particularly valuable given the tendency for systems to immediately change following a serious event, and for hindsight bias to cloud judgement in understanding what really happened. Indeed, since this approach is prospective, it helps to identify and remove problems before they accumulate in sufficient numbers to cause adverse events. Another key feature of this work is its interdisciplinary nature. Employing clinical expertise (surgeons, nurses, anaesthetists) and non-clinical expertise (human factors, systems analysts) is extremely powerful, and distinctly advantageous given neither type of expert may fully understand all the implications of their observations[12 29 30] The multidisciplinary nature of the work has also benefited both types of experts. It has helped clinicians recognise the importance of human factors in achieving optimal patient outcomes, and helped human factors experts understand the unique demands of healthcare, and recognise where approaches from other industries (such as aviation) require adaptation.[31]

Direct, prospective observation and systems analysis methods have demonstrated the value of looking deeper into complex error-prone systems to develop higher-level quality improvement initiatives. This identification of a broad range of system problems has facilitated a better understanding of human abilities and has afforded greater opportunities to help clinicians avoid and deal with error. It has also led to the development of new systems of work to reduce workload and encourage smoother workflows. The evolution of human factors work in surgical safety reflected in the work reported by Gurses *et al* (this issue)[27] illustrates the growing interest in design and a complete systems approach that encompasses, yet goes beyond teamwork, training and checklists. While there is a clear need to understand and address the issues they identify, there also is the well-recognised need to understand how best to bring about desired changes in healthcare systems. There is also the perennial problem of how to measure the effects of combinations of interventions in complex systems.

The legacy of Bristol, Winnipeg and the safety movement is that of moving our understanding of error from the 'sharp end' to the 'blunt end', and of clinical success from outcomes to process. As a result, we are becoming increasingly knowledgeable about how to improve, support and develop human performance in surgery; the role of teamwork and communication in generating or recovering from errors; how to begin to make change; and how to continually improve. Starting in high-risk surgery, where patient outcomes were clearly observable, and moving to more detailed techniques in lower risk but more common surgeries, the value and depth of direct observational methods have been established. This research emphasised, in particular, the complexity and tightly coupled nature of cardiac surgery,[32] and the value of the human factors perspective—which embraces the complex relationship between people, equipment, processes and organisations—in understanding safety in both high-risk and lower-risk surgery. With the new understanding provided in this issue (Ref Gurses, this issue)[27] we can begin to understand how the workspace can be developed to improve all these aspects of healthcare delivery. Now, more than ever, we need good designs, a systems approach to improvement, and we need to measure the impact that this work is having on outcomes.

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Understanding safety and performance in the cardiac operating room: from 'sharp end' to 'blunt end'

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Characterizing Trauma Systems: Comparison of Methods for Identifying Improvements

Running Title: Human Factors and Trauma

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Abstract

Introduction: Interventions to improve trauma systems may involve communication patterns, team performance, the altered environment or equipment design. To validate these interventions the impact on the entire trauma system must be characterized. We postulate that observational methods based on human factors principles would identify unique trauma related issues, as well as the frequency and nature of disruptions, better than standardized surveys or focus group interviews.

Methods: Providers at a civilian trauma center completed safety attitude surveys and focus group interviews to identify barriers to optimal performance. Trauma teams activated for 90 high level traumas were also studied prospectively by trained observers to identify flow disruptions using a validated tablet data collection tool.

Results: Survey results indicated neutral orpositive attitudes towards patient safety. Focus groups identified coordination (31%) and protocol deviations (21%) as common causes of frustration, with some confusion over leadership, and little opportunity for debriefing after major events. Trained observers following 90 casesrecorded1757 flow disruptions, with a mean of 20.4 (95% CI ± 5.45) per case and 11.9 (95% CI ± 1.78) per hour. Disruptions due to coordination and communication were significantly more frequent than other types.Although no impact on the process was noted in 48% of flow disruptions, 64 of 86 cases (74%) experienced at least one moderate delay or full case cessation. Coordination problems accounted for 37% of these delays.

Conclusion: Leadership and teamwork, patient factors, equipment issues, and communication and coordination within the team and between other essential services, reflected weaknesses that might benefit from further consideration and intervention. Direct observation of flow disruptions during trauma care facilitated a better understanding of trauma systems than surveys or focus groups alone. The next phases of our research will use flow disruptions as an outcome measure to assess the effect of different interventions.

Introduction

High quality trauma care demands a complex orchestration of tasks, technologies, resources, people and information from pre-hospital hand-offs with the emergency department, through diagnostic consultation and imagery, to the interface with the operative and post-operative environment. While traditional approaches to healthcare systems attribute success or failure primarily to the senior physician [1], it has become apparent that the interactions between the many components of care processes can also make the difference between life and death[2]. Indeed, failure of healthcare systems to support the work of physicians, nurses and other caregivers has led to a gap between the care we would like to deliver, and the care that we actually deliver[3,4]. Characterizing the particular demands of complex trauma care systems to identify problems that can impact human and process performance and then addressing those problems through targeted interventions built on a complex, validated understanding of the system, might help reduce adverse outcomes and improve the care delivered as well as reducing costs and improving working lives[5].

The identification of appropriate interventions needs to provide accurate insight regarding problems and solutions with the trauma system and must also assist in an understanding of the impact of the intervention on the wider system. There are several risks when attempting to improve performance in trauma care. First, seemingly simple problems may hide a wealth of causational complexity[6,7], creating opportunities for causal misattribution. Second, solutions that appear simple can be difficult to implement effectively, especially within time, staffing and resource constraints of an acute trauma episode[8,9]. Third, sustaining change can be challenging, especially if the proffered improvement does not add substantially to the quality of care or the experience of the practitioner[10]. Finally, interventions can have unexpected effects[11], where one problem is solved, at the expense of other aspects of performance. Given the time and the effort involved in making and sustaining change in a complex system, it is vital that the most important problems are identified and the most appropriate solutions developed. Thus, we chose to integrate and compare the results of three methods for system evaluation and improvement.

A commonly used method for systems diagnosis in large hospitals is through surveys. These are relatively inexpensive to administer, while offering the potential for a large sample size and statistical evaluation. For example, surveys are extensively employed to assess teamwork, culture and cultural improvement[12–14]. However, surveys offer limited opportunities for qualitative descriptions that may be essential for deeper systems understanding. Another commonly used method for systems diagnosis and improvement is provider based interviews, which can offer detailed, complex narratives associated with systems faults. Through direct practitioner involvement they also purport to offer clinical engagement and validity, but the data produced can make quantification and prioritization difficult. In surgical care, direct observational studies of the process are frequently employed[15–17]. Such methods can offer both quantitative data that allows statistical manipulation, modeling, evaluation and prioritization, and qualitative descriptions that allow a deeper understanding of system complexity that informs and leads to solutions. Thus, though expensive and methodologically challenging, direct observation of deviations

from the natural progression of care – previously defined as “flow disruptions”[16] - may be best suited to provide a detailed view of systems defects. We sought to compare the relative utility of the three methods for identifying weaknesses in our trauma systems.

A comprehensive analysis of a civilian trauma centerwas undertaken utilizing three unique assessment methods in order to characterize our trauma system and to evaluate different system diagnostic methods for identifying and eventually testing evidence-based interventions. By assessing different methodologies to characterize our trauma system, we hoped both to identify a broad range of potential systems improvements, and to gather evidence about which method or methods are best suited toidentify future improvements in trauma care systems.

Methods:

Data was collected from January to December 2011 to characterize deviations in the normal progression of trauma care ata civilian trauma center. All data collection studies were individually reviewed and approved by the Institutional Review Board of the Cedars-Sinai Medical Center.

For the survey, the Safety Attitudes Questionnaire (SAQ)[14] was adapted by a team of human factors engineers (DW,RB), systems experts (JB,RK,CK), and clinicians (EL,DS) to focus on elements specific to trauma. It was then distributed to the physicians, nurses and other practitionerswho provide trauma care. The survey consisted of 27 questions requiring an answer on a 5 item Likert scale from “Strongly Disagree” to “Strongly Agree”, which were amalgamated along 5 dimensions (Teamwork; Assertiveness; Safety; Equipment; Organization), with scores converted into percentages (Figure 1A). Eight questions were phrased negatively, and these were reverse coded for the analysis. All responses were anonymous. To maximize response rate, multiple survey recruitment communications were provided to the ED and Trauma staff, and multiple opportunities were presented for staff to complete the survey.

A total of 30 interviews were conducted with 73 health care providers or allied health care staff, where possible in a focus group settingor individually. Participating staff consisted of 16 paramedics, 14 emergency department attending and nursing staff, 3 general surgery residents, 3 radiology physicians, 2 pharmacists, 9 blood bank staff, 3 emergency department technicians, 3 operating room staff, 6 case managers, 6 critical care nurses and 8 trauma team attending liaisons from surgery, orthopedics, neurosurgery, anesthesiology and pediatric critical care. Focus groups were conducted separately for each specialty area in order to encourage participants to feel comfortable expressing their opinions. Responses were recorded and later transcribed in note form, with the text then frequency-analyzed to identify situations that suggested opportunities for improvement (Table 1A).

For the direct observation component of the study, human factors researchers and medical students with training in human factors methods observed trauma cases over a ten-week period. Observers followed patients through the trauma care process from arrival in the emergency department (ED) until the patient was either admitted to the floor, ICU or discharged. All patients were considered high level traumas requiring assistance from the in-house trauma team. Multiple trauma teams were observed in multiple trauma bays, imaging rooms and operating rooms within the hospital. Data was structured around a tablet-PC data collection tool based on a previous version described elsewhere[18], which was

adapted for trauma care following a four-week paper-based pilot data collection period. Observers noted any event that disrupted the flow of the trauma care process. The flow disruption type was categorized according to the definitions and examples in Table 2. Flow disruptions were time-stamped by the software and categorized by observers in real time according to (1) category of flow disruption; (2) the potential and/or actual impact of the flow disruption; (3) the trauma team member affected by the flow disruption. A free-text description of the flow disruption was also required. Other contextual data was also collected, including the time patient arrived, trauma level (100 or 200), and the location of the flow disruption (ED, Radiology, OR orduring transitions). On arrival to the emergency department, the scheduled observer would immediately begin collecting data using the Tablet-PC based data collection tool. Most of the trauma team members were aware of the study, however, if a team member was not aware of the research, the observer would explain the study briefly and distributed additional information sheet regarding the study if needed. The observer then found a location in the trauma bay that did not interfere with the trauma staff work flow. The observer would follow the patient until the patient was either admittedto the floor or discharged. The observers did not actively engage in conversations with the trauma or surgical staff during the cases to minimize the possibility of a staff member being distracted. This also ensured that the team carefully captured events that occur during the cases.

Descriptive statistics were summarized using raw percentages, means and standard deviations in addition to 95% confidence intervals (CI). Multiple paired comparison t-tests were used to compare differences between flow disruption types, with a Bonferroni correction applied for 45 significance tests generating a significance level of $p<0.0011$.

Results

Survey

A total of 41 surveys were completed (Figure 1A).Responders reported strongest agreement with question 10, “I would feel safe being treated here as a patient,” and question 24, “We have reliable and high-quality equipment”. Responders reported the weakest responses to question 20, “Things do not ‘fall between the cracks’ when transferring patients”, and question 7, “Briefings are common in this clinical area”. Questions with large confidence intervals were also of interest as these reflect a broad range of responses, such as question 6, “I know the first and last names of all the personnel I worked with during my last shift”. Overall, this data presents a largely neutral or slightly positive view of the trauma service, and little differentiation between questions. Aggregating questions based on their dimensions (Figure 1B) suggests that perceptions of equipment are slightly more positive, and perceptions of management slightly less positive, than other dimensions, though the differences are minimal.

Interviews

From the interview data (Figure 2), the steps most in need ofimprovement werecommunication (33%) and primary and secondary survey (33%). Lack of coordination was cited as the most common source of frustration (31%), followed by not following protocol (21%) and lack of communication (16%). There was

clearly a difference in the perception of who was in charge, with just under half believing it was the attending trauma surgeon, with the remainder divided equally between the ED attending and nurses. The majority of responders also stated that few debriefings took place, even after serious events. Additional findings from the wider discussions related to issues in trauma bay care, blood bank coordination, and the transition from ED to the OR, (Table 1B). Trauma bay care was challenging because of the larger number of non-essential people, excess noise levels, inaudible communication and missing supplies or equipment. Blood bank coordination was difficult due to mislabeled specimens, lack of adherence to specimen protocol, excessive time on the phone resolving issues due to failure to follow blood bank policy, and failure to update the use of blood products from refrigerators. Trauma patient transition to the OR required holding urgent cases, the resultant problems when starting a trauma case and the need to complete elective cases during trauma cases which limits resources, especially at night.

Direct Observation of Trauma Care

Though 90 cases were initially observed, a total of 86 cases were included in the analysis owing to incomplete data sets for four cases. 14 cases were at the higher level trauma activation and 72 at a lower level, with 6 cases going to the OR. The average case duration was 101(95% CI ± 12.4) minutes. Observers noted 1757 FD, with a mean flow disruptions per case of 20.4 (95% CI ± 5.45) and a mean rate of 11.9 (95% CI ± 1.78) per hour. When classified into type (Figure 3A and 3B), coordination problems accounted for 31% of the flow disruptions, with communication at 21% and patient factors at 13%. This is also reflected in the number of flow disruptionsper case, which are most commonly due to poor team coordination (6.34/case± 1.98; 3.86/hour ± 0.82), communication breakdowns (4.25/case±1.33; 2.42/hour ± 0.52), and patient factors (2.74/case±0.82; 1.6/hr± 0.41).These categories demonstrate significant differences between each other(Table 3), indicating substantial differentiation between types and thus between sources of flow disruption. In particular, communication and coordination are significantly different from all other types.The impact of the flow disruption on the processwas most commonly momentary delay (37%), followed by acknowledged but no delay (36%), no impact (12%),moderate delay (12%) and full case cessation (2%). In 64 of 86 cases (74%) at least one moderate delay or full case cessation was noted.This is also reflected in the rates of different disruption impacts per case (Figure 3C). Finally, we combined types and impact (Figure 3D) which allows us to compare flow disruptions types where there was no delay,with others where there was a momentary or more delay. Coordination problems, patient factors and to a lesser extent equipment factors show greater propensity to create process problems, as opposed to communication problems and external interruptions which, though frequent, are less likely to create a delay. Therefore, the nature of flow disruption and error causation in trauma care are multi-factorial.

Discussion

We undertook a comprehensive analysis ofa civilian trauma systemutilizing three unique methods in order to better understand the nature of inefficiency, delays, risk and poor outcomes. Overall, leadership and teamwork,patient factors, equipment issues, and communication and co-ordination within the team and between other essential services, reflected weaknesses that might benefit from further consideration and intervention. In contrast to other studies, coordination, rather

than communication[19,20], was the most frequent problem, reflecting the intra-departmental complexity of trauma care. It was also possible to explore the strengths and weakness of each method to compare efficacy. The questionnaire suggested neutral or slightly positive attitudes towards safety and teamwork, though there was little differentiation between questions. In comparison, group interviews suggested coordination breakdown, deviations from protocol, leadership, and lack of debriefing as areas of potential improvement. This method of open ended enquiry clearly provided a more robust source of information than the questionnaire surveys. Using human factors methods to record flow disruptions by direct observation provided an even richer range of data, possessing properties of both other methods – quantified data and a large sample size to allow statistical modeling, with qualitative observations to allow further detailed systems diagnostics. Clearly, the survey data reveals least about potential system improvements. While the interviews and observations are in general agreement, the detail of both type and impact of different flow disruptions provided a huge advantage in validity and analytical potential over the interview results. The disadvantage of direct observation is the need for observers and appropriate analytical methods, both requiring human factors expertise. As no trauma system is perfect, direct observation of flow disruptions is well suited to understand the nature of trauma systems and to identify interventions that might improve the process and eventual outcomes of trauma care.

The use of human factors methods to record flow disruptions has received increased attention as a way to improve safety, efficiency and cost of health care[18,21–29]. Direct observation in particular has been used to assess healthcare systems in terms of teamwork[30,31], training interventions[25,32], equipment design[33], decision making[34,35], human errors[16,36], and causes of adverse outcomes[2]. Flow disruptions provide a “window” into the system of care[37] which allows the identification of improvements in safety before serious adverse events occur, leading to improvements in processes and efficiency. Though the relationship with outcome is not direct, others have demonstrated an association between flow disruptions and surgical errors[16,17,36,38], andfurther analysis of the clinical implications for these flow disruptions is underway[39]. Though multiple methods of systems analysis are desirable, our study suggests that the use of trained observers to capture flow disruptions during trauma care may be superior to other methods; or at least extremely valuable to validate and further develop findings from interviews. The direct observation of flow disruptions in trauma care provides insights into risk and inefficiency with the healthcare systems not offered by other methods, while providing the opportunity to examine further the mechanisms that affect care delivery, and enhance the understanding of the relationship between humans, systems, patients, and outcomes. Our next phase of research will be to validate interventions utilizing direct observations of flow disruptions. We intend to implement teamwork training, standardizing the OR, briefing prior to patient arrival, trauma headsets, standardized patient hand-offs and shared information displays, which we will then evaluate using direct observation of flow disruptions to assess their effect and likely contribution to efficiency and performance improvements.

Limitations to our research require further discussion. Though the design of the survey limited the utility, as yet we have not encountered a validated instrument more widely used than the SAQ on which our survey was based[14]. For the interviews, directly transcribing everything that was discussed was not possible, which may mean analytical potential was lost.Word-for-word transcription and

detailed thematic analysis may extend the benefit of these data, though we suspect that the proportionally higher effort would have offered limited extra value. Observations were dependent on the skill of the observer, which was enhanced and normalized through training and cross-observation between the human factors and medical students. Observer variabilitymay have introduced related biases, which we did not examine here, but will be assessing in a future study. Video analysis may also enhance understanding of observer skill and flow disruption impact[40]. Seasonal effects may have elicited bias;the survey and focus group interviews were conducted in the winter and spring, while the trained observers characterized the flow disruptions in the summer and fall. In academic medical centers, where residency is a key component of the trauma systems, the time of year may affect the responses provided or the flow disruptions observed.However, we suspect this effect would be minor, and should not alter the core observation of flow disruptions. A small number of patients with the worst prognosis in the ED and the worse outcomes had a particularly high number of flow disruptions. Further analysis of these cases is necessary and valuable, and is currently underway[39].

In conclusion, we conducted comprehensive trauma systems reviews using available methodology to characterize common causes of inefficiency, risk and adverse events. Our findings indicate that objective observations based on human factors principles facilitate a better understanding of trauma systems than surveys and focus groups alone. We recommend that any trauma center attempting systems analysis and work improvement dedicate a proportion of their data collection to direct observation. Human factors observational research techniques are an increasingly valuable tool at enhancing our understanding of trauma systems by providing quantitative and qualitative understandings of performance and process in trauma care. Eventually we hope to demonstrate better human performance, and better patient outcomes.

AUTHOR CONTRIBUTIONS

Literature Search: Ley, Wiegmann, Blaha, Blocker, Shouhed, C. Karl, R. Karl, Gewertz, Catchpole

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Data Analysis: Ley, Wiegmann, Blaha, Blocker, Shouhed, Gangi, Rush, Taggart, C. Karl, R. Karl, Gewertz, Catchpole

Data Interpretation: Ley, Wiegmann, Blaha, Blocker, Shouhed, Gangi, Rush, Taggart, C. Karl, R. Karl, Gewertz, Catchpole

Writing: Ley, Wiegmann, Blaha, Blocker, Shouhed, Gangi, Rush, Taggart, C. Karl, R. Karl, Gewertz, Catchpole

Tables: Ley, Wiegmann, Blaha, Blocker, Shouhed, Gangi, Rush, Taggart, C. Karl, R. Karl, Gewertz, Catchpole

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Figure 1A: Survey Results

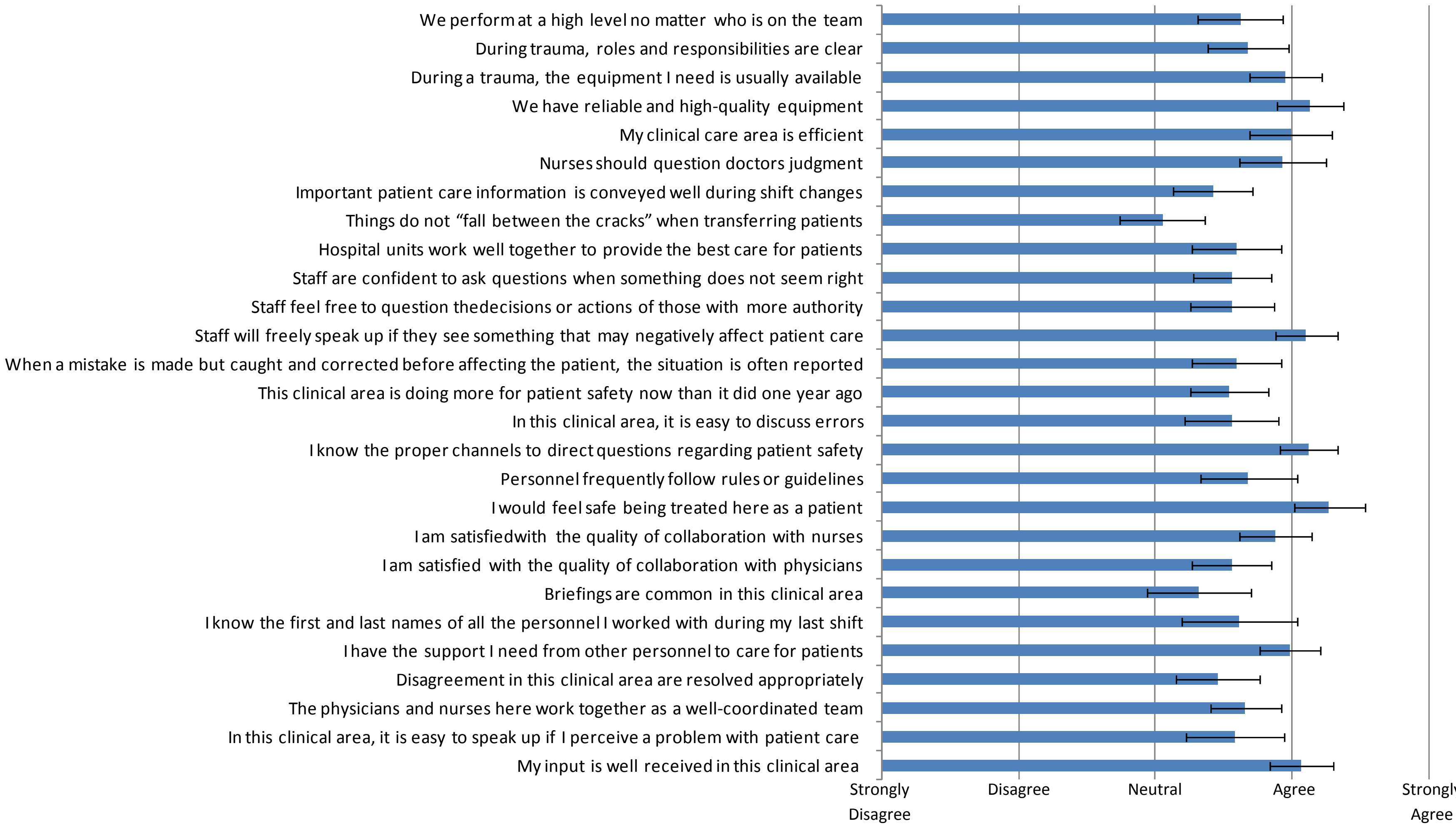


Figure 1B: MergedSurvey Results

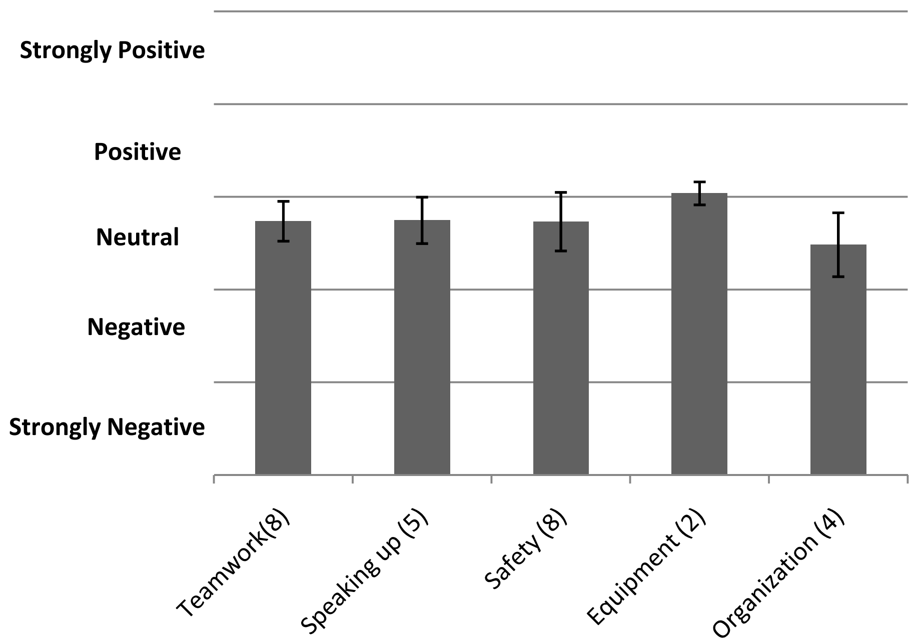


Figure 2.Focus Group Interviews

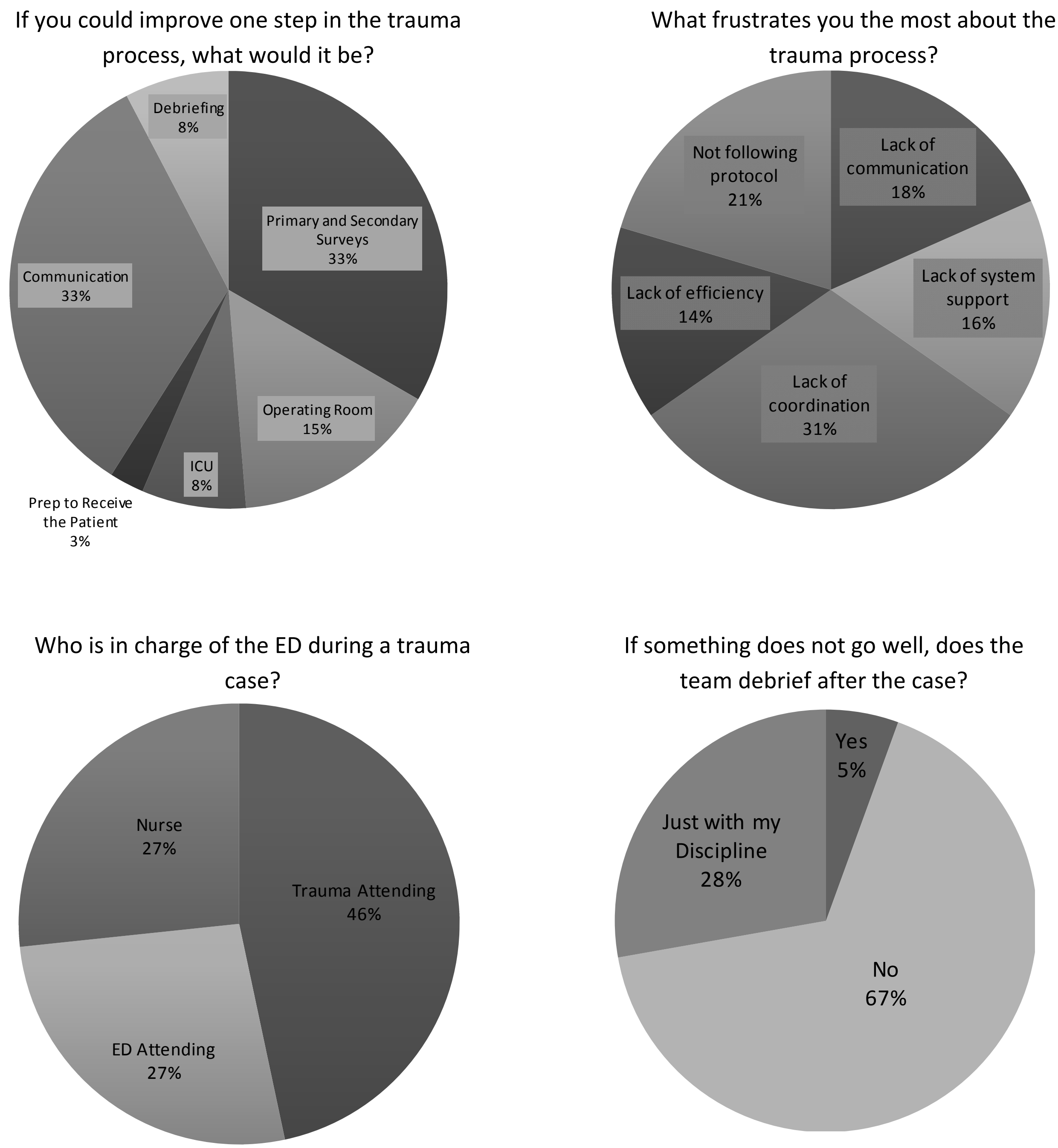
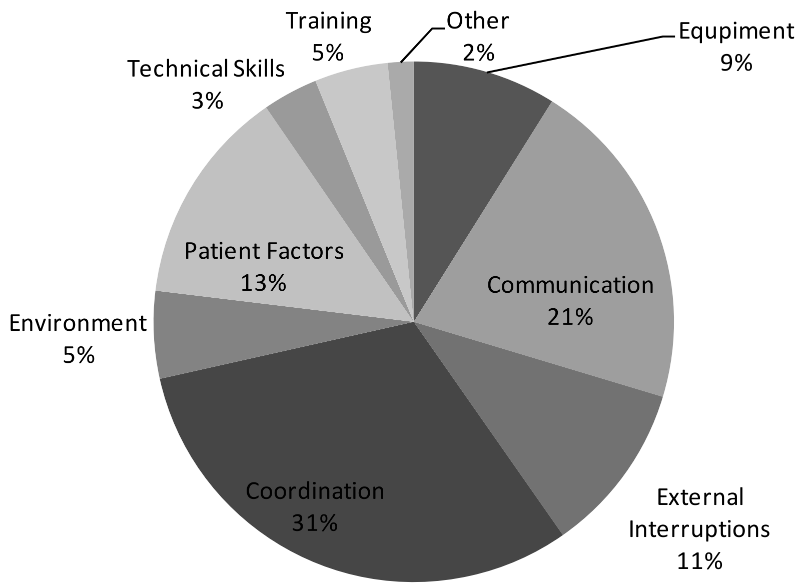
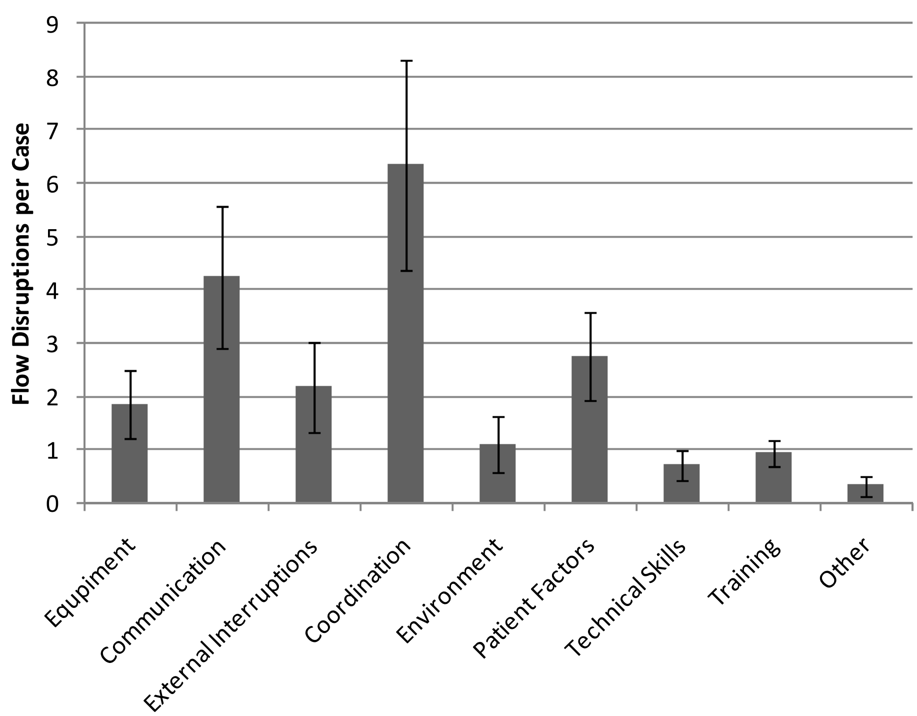


Figure 3A-D. Flow disruptionsduring trauma care

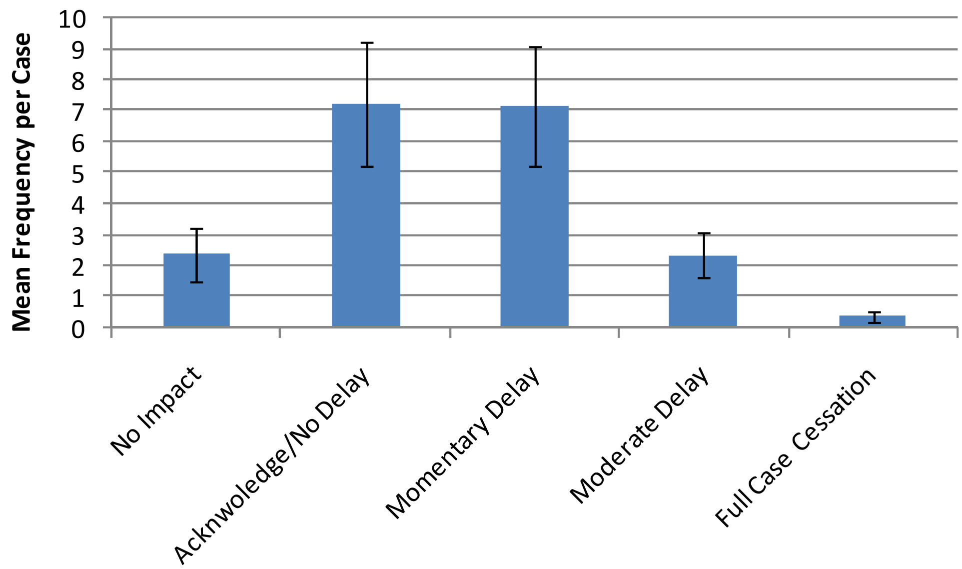
A. Flow disruption types



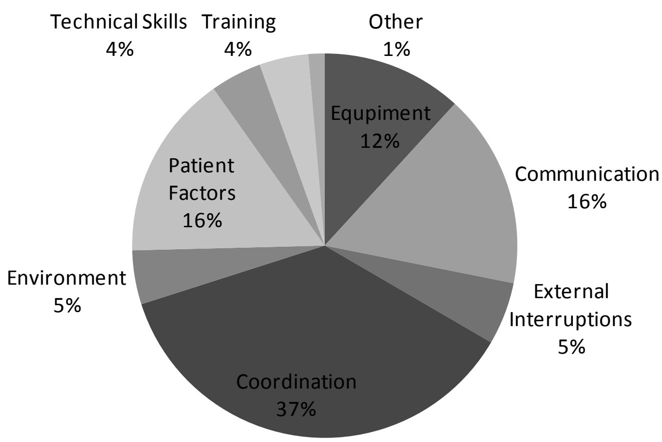
B. Flow Disruption per case



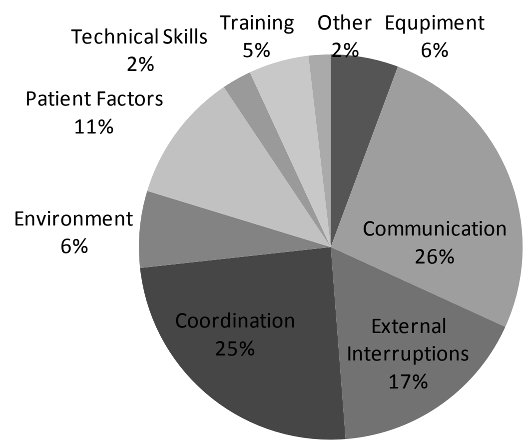
C. Impact of Flow Disruptions



D. Flow disruption type at varied delay



Type with momentary delay or complete case cessation



Type with no impact or delay

TABLE 1A: Interview and Focus Group Questions

Theme	Questions
GENERAL	• Think of a trauma case that went well. What made it go well? • Think of a trauma case that did not go smoothly. What went wrong?
PROCESS ISSUES	• If you could improve one step in the trauma process, what would it be? • What frustrates you the most about the trauma process? What would you do to change it? • What distractions and delays are present? • Are there any policies or procedures that are consistently not followed? • How does technology impact the trauma process?
LEADERSHIP & TEAMWORK	• Who is in charge in the ED and OR? • What makes a good trauma leader? What actions or behaviors does a good leader exhibit? What is different about what they do? • What happens when a team member does not show up? • If something does not go well, does the team debrief after the case?
ORGANIZATIONAL ISSUES	• What typically gets in the way of a new idea or practice? • How well does the ED and the OR work together? • How well do anesthesia and surgery work together

TABLE 1B. Findings from Trauma Focus Group Interviews

Bay Care	• Number of people was large – some essential, and some non-essential. • Excessive noise levels • Some communications inaudible • Missing supplies or equipment
Blood Bank Coordination	• Mislabeled specimens • Lack of adherence to specimen protocol • Excessive time on phone resolving issues emanating from failure to follow policy and from misunderstandings. • Failure to inform blood bank of use of blood product from refrigerators
Operating on trauma patients	• OR having to hold up cases to allow urgent trauma surgery • Resultant problems when starting a trauma case • The need to complete elective cases during trauma caseswhich limits resources, especially at night

TABLE 2: Flow Disruption Definitions and Examples

FD Category	Definition	Example
Communication	Disruptions that involve the verbal transition of information between at least two team members	“Nurse asked the trauma resident to speak up because too many people were talking”
Coordination	Disruptions that involve the interaction with some piece of equipment as well as at least one other team member	“Another patient was in the scanner when the trauma patient arrived at CT”
Environment	Disruptions affecting the auditory or visual status of the operating room and not directly relevant to the treatment of the patient	“X-ray tech had difficulty getting the x-ray machine into the operating room”
Equipment	Equipment problems hindering the smooth progression of the trauma team procedure	“Portable monitor was malfunctioning”
External Interruptions	Disruptions imposed on the procedure from outside, which include extraneous people, phone calls, or intercom messages that did not relate directly to the procedure at hand	“Resident’s phone was ringing while he was scrubbed in the OR”
Patient Factors	Disruptions specifically involving patient-relatedfactors	“CT scan had to restart because the patient was moving”
Technical Skills	Skill-based or decision (thinking) error, including poorly executed tasks, omitted steps,or misinterpretation of relevant information	“Resident did not know how to properly connect the monitor”
Training	Training or supervision that hinders the natural progression of the trauma team procedure	“Attending was showing the resident how to perform a FAST scan”

TABLE 3: Comparison between flow disruption types. Italics indicate significance

	Equipment	Communication	External Interruptions	Coordination	Environment	Patient Factors	Technical Skills	Training
Equipment	x	x	x	x	x	x	x	x
Communication	*t=4.6 p<0.0001*	x	x	x	x	x	x	x
External Interruptions	t=0.97 p=0.33	*t=-3.98 p=0.0001*	x	x	x	x	x	x
Coordination	*t=5.48 p<0.0001*	*T=3.99 p=0.0001*	*t=5.35 p<0.0001*	x	x	x	x	x
Environment	t=-3.36 p=0.0012	*t=-5.62 p<0.0001*	*t=-3.47 p=0.0008*	*t=-6.11 p<0.0001*	x	x	x	x
Patient Factors	t=1.95 p=0.0545	t=-2.01 p=0.0474	t=1.09 p=0.275	*t=-3.52 p=0.0007*	t=*4.10 p<0.0001*	X	x	x
Technical Skills	*t=-4.72 p<0.0001*	*t=-5.79 p<0.0001*	*t=-3.71 p=0.0004*	*t=-5.98 p<0.0001*	t=-1.79 p=0.0762	*t=-5.12 p<0.0001*	x	x
Training	t=-3.09 p=0.0027	*t=-5.32 p<0.0001*	t=-3.22 p=0.0018	*t=-5.77 p<0.0001*	t=-0.72 p=0.468	*t=-4.27 p<0.0001*	t=1.27 p=0.2071	x
Other	*t=-5.5, p<0.0001*	*t=-6.19, p<0.0001*	*t=-4.74 p<0.0001*	*t=-6.24 p<0.0001*	*t=-3.62 p=0.0005*	*t=-5.78 p<0.0001*	t=-2.87 p=0.0051	t=*-4.36 p<0.0001*

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Barriers to Efficient Trauma Care Associated with CT Scanning

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ABSTRACT

Background: Trauma care must be delivered to unstable patients with frequently unknown medical histories, under time pressure, with a need for multi-disciplinary collaboration. A better understanding of the process could reduce errors, and improve quality, efficiency, and patient outcomes. Previous analysis of our data indicated that radiology phase of trauma care was particularly prone to deviations from optimal care.

Study Design: Disruptions to the flow of trauma care during high level trauma cases were observed over a ten-week period at a Level-I trauma center. Using a validated tablet data collection tool, the type, nature and impact of these small disruptions to efficient care were recorded. Post-hoc, two physicians reviewed the descriptions of the flow disruptions and assigned a clinical impact score to each.

Results: 581 flow disruptions were observed during the radiological care of 76 trauma patients. An average of 30 minutes (95% CI ± 3 mins; range 7-98 mins) was spent in the CT scanner, with a mean of 14.5 (95% CI ± 2.7) flow disruptions per hour. Coordination (34%), communication (19%), interruptions (13%), patient factors (12%), and equipment (8%) were the most frequent disruption types. Clinical and observer impact scores were in general agreement ($p<0.0001$). The detailed analysis of 103 high impact disruptions found the main problems to be patients moving, ordering systems, equipment availability and teamwork issues.

Conclusion: Although flow disruptions cannot be eliminated completely, interventions might be tested to address these disruptions. Solutions to improve teamwork, ordering processes, equipment supply and maintenance, briefings, checklists, and patient information are suggested.

INTRODUCTION

Trauma care systems should be designed to ensure that severely injured patients receive the timeliest and most appropriate care.Unfortunately, small errors and deviations from optimal caremay be common. Estimates suggest that more than 20% of trauma deaths may be potentially avoidable[1] while approximately 2% of trauma deaths may be directly attributable to clinical errors[2]. This is a reflection of the challenges faced in delivering optimal trauma care; unstable patients with frequently unknown medical histories, time pressure, and need for multi-disciplinary collaboration.Trauma teams are composed of different specialists with diverse abilities, often rapidly formed, with interdependent tasks. This care is complex work in a high technology domain[3]requiringcoordination across different physical and intra-organizational locations. Abetter understanding of the weaknesses and strengths of trauma systems to improve quality, reduce errors, and ultimately positively impact outcomes is necessary.

Human factors is the study of the relationship between people and systems that has helped to understand how industrial accidents occur [4], and the system design parameters involved in safe and efficient care[5]. Direct observation of surgical care delineates the complex relationship between processes, teamwork and outcome[3], and can provide a rich analysis of normal system function that can suggest effective quality and safety improvements[6,7]. A variety of human factors studies examine various aspects of trauma care [8,9]; however, no studies have attempted a comprehensive systems analysis based on direct observation of trauma care.

The present analysis derives from a 2 year project describing work in a single Level-I trauma center. This investigative work has resulted in 2 published or submitted papers. In the first, we provided an overall systems analysis and concluded that the direct observation of flow disruptions – defined as deviations from the natural progression of care [7] - was a valuable data collection and analysis method. In a second paper, we provided further analytical detail with a multi-factorial analysis of the process of trauma care from the perspective of type, location, and clinical impact[10,11]. Taken in whole, our evidence suggested that systems problems during computed tomographic (CT) scans were particularly salient.In this paper, we use observational data tofurther explore the nature of disrupted flow in trauma radiology andsuggest specific improvement interventions.

METHOD

Participants in the study were members of a trauma care team that performed normal activities in the emergency department (trauma bay), radiology suite, and OR during observational periods at an 878-bed tertiary Level-I metropolitan non-profit academic medical center.

Researchers and medical students with training in human factors collected prospective observational data during trauma cases over a ten-week period. The cases observed were all considered high level traumas requiring assistance from the in-house trauma team.Observers

would report promptly to the emergency department once a trauma was activated, and collected information about the trauma care process from the time the patient arrived in the emergency department (ED) until the patient was either admitted to the ICU, the floor, or discharged. Observations were conducted in multiple trauma bays, imaging rooms and operating rooms within the hospital. Multiple trauma teams were observed throughout the observation period.

The medical students weretrained during a comprehensive tutorial which included an introduction to human factors, introduction to direct observations techniques and observing a trauma casewith a human factors researcher. This ensured that the medical students were able to properly identify and categorize flow disruptions as defined in previous studies [7,12]. This was followed by a post-case debriefing session, where problems such as event classification difficulty, technical problems with data collection tools, additional case details that could not be captured elsewhere on the tool, and event timing issues could be resolved. Following initial pilot studies with a paper-based version of the data collection method, a tablet-PC data collection tool used in surgery and described elsewhere [13]was re-designedprior to commencement of full data collection.This created a trauma-specific flow disruption data collection method, facilitated data input and management, and allowed easier post-hoc analysis.The tablet-PC data collection tool was based on the Systems Engineering Initiative for Patient Safety (SEIPS) Model[5] and had an established reliability of 87% agreement between a pair of observers[13].

INSERT TABLE 1 HERE

Flow disruptions were time-stamped and categorized by observers in real time according to (1) type of flow disruption (Table 1); (2) the impact of the flow disruption on a scale from 1 to 5(1=no impact; 2=acknowledge/no delay; 3= momentary delay; 4=moderate delay; 5=full case cessation); (3) the phase (ED, Imaging, OR) in which the flow disruption occurred; and (4) a free-text description. After all data were collected, a physician (DS) reviewed the descriptions of the flow disruptionsand assigned a clinical impact score to each, with a random selection reviewed and confirmed by an attending trauma surgeon. The scoring ranged from 0-3. A score of 0 denoted that observed FD had no impact on the case. A score of 1 meant that the FD had minimal impact on the case and did not distract from the natural progression of care. A score of 2 meant that there was cessation of the case, but the pause was <2 minutes. A score of 3 reflected case cessation for >2 minutes or case cessation of less than 2 minutes with significant consequences to patient care (e.g. blood not in room, ventilator malfunction).

The need for a sub-analysis of radiology data was identified through a global assessment of flow disruption types and rates[11].Only data associated with flow disruptions in the radiology phase of care was included, with all other data excluded from the present analysis. A chi-squared test was used to examine the relationship between observer and clinical impact scores.

RESULTS

76 out of 86 (89%) trauma cases observed were taken to the imaging department. 581 of 1757 flow disruptions (33%) occurred during the radiology phase. Patients spent average of 30 minutes (95% CI ± 3 mins; range 7-98 mins) in the CT scanner. We calculated a mean of 7.6 (95% CI ± 2.1) flow disruptions per case and 14.5 (95% CI ± 2.7) flow disruptions per hour during the radiology phase.

Most of the flow disruptions were classified as unfavorable coordination issues (34%), withcommunication failures (19 %), external interruptions (13%), patient factors (12%), and equipment issues (8%) also commonly identified (Figure 1). These five categories collectively accounted for approximately 12 disruptions per hour. *Coordination problems* generally related to the complex amalgam of team and task requirements in trauma care. In simple terms, this can be described as having the right people, the right equipment and the right information in the right place at the right time. *Communication flow disruptions*often involved misunderstandings about CT scan orders and patient condition. External interruptions included extraneous people, phone calls, or intercom messages that did not relate directly to the current procedure or patient. Flow disruptions related to patient factors generally involved patient unwillingness or inability to cooperate (e.g. constant movement during CT scanning).

INSERT FIGURE 1 ABOUT HERE

We examined the two measures of impact which we defined as observer impact estimates and clinical impact estimates. The majority of the observer impact estimates were identified as momentary delay (35%) or acknowledge/no delay (31%). 14% were classified as having moderate delay, 13% as having no impact and 3% classified as full case cessation (Figure 2). The observers identified 17(24%) of the 76 cases as having a flow disruption that caused a full case cessation during the radiology phase. Post-hoc clinical impact scoring demonstrates a slightly different distribution (Figure 3), with aminimal clinical impact in 66% of all instances, 13% with no impact, 15% with a pause of less than two minutes, and 6% with a pause of >2 minutes. Although there is some inconsistency between impact estimates, there is generalagreement between scores (Figure 4), with a chi-square test demonstrating that there is a significant relationship between the impact scoring methods (χ^2= 108.72, p<0.0001).

Combining impact scores into low (No Impact + Acknowledge/No Delay; No Impact + Minimal), and high groups (Momentary + Moderate + Cessation; Pause > 2mins + Pause < 2 mins) we then examined the FD types within those groups (Figure 5).According to both methods of impact estimation, coordination, patient factors, communication and equipment had higher effects on performance in CT than the other flow disruptions. Finally, we took disruptions that

had a high impact score from the perspectives of both the observers and clinicians within these four categories and further classified those 103 flow disruptions into themes based on the description of the event (Table 2). This identified that patients moving during their CT scan was the most frequently observed flow disruptions. Problems with CT orders, technical skills problems, team member absences and equipment availability were also salient disruptions.

INSERT FIGURE 3 ABOUT HERE

INSERT FIGURE 4 ABOUT HERE

INSERT FIGURE 5 ABOUT HERE

INSERT FIGURE 6 ABOUT HERE

INSERT TABLE 2 ABOUT HERE

DISCUSSION

In this sub-analysis of our larger observational study, the 582 flow disruptions identified during the radiology phase of the trauma care occurred at a rate of more than one every 5 minutes. While impacts varied,it was revealing that, on average, a 30 minute stay in the CT scanner was associated with at least one high impact delay or pause. These were mostoften caused by coordination, communication, equipment and patient-related issues. Though external distractions were frequent, they had a much lower impact.There was good agreement between the impact estimates, and in the types that were of highest impact. The final analysis which looked in detail at the causes of the most frequent high impact disruptions, most commonly identified issues related to patients moving, ordering systems, equipment availability and teamwork issues.

The focus of most studies related to CT scans has been on the interpretation of images[14,15], and the clinical utility of CT scans in the initial assessment of trauma patients[16,17]. A review of recent literature revealed several studies on improving radiology care [18,19,20], but no study to our knowledge has focused on trauma patients' passage through radiology or the systems componentsassociated with the efficient processing of a patient through the radiology phase of trauma care.

In the rapid transit of the patient from the ED to the radiology room the trauma care process can be fragmented and uncoordinated. Team members maybe adjusting simultaneously to one another andaddressing and prioritizing patient care needs. Patient instability coupled with time pressures to get to the CT scanner means that appropriate scans may be incorrectly ordered or missed, which was a particular problem within this trauma center. Patients were frequently in pain, confused, or unclear about what was happening or their need to be still during scanning. Distractions from phone calls and pagers and unavailable or malfunctioning equipment exacerbate these difficulties. We argue that these flow disruptions make it challenging for a team

to efficiently and effectively deliver the optimal care. While we understand that flow disruptions during the trauma care process cannot be eliminated completely, we argue that interventions can be implemented to mitigate the vulnerability that disruptions present to the safety of patients.

Clearly, one method of improvingcoordination and communication among team members might beby enhancing team function. In the organization studied, there was no consistent approach to team and leadership training, for which there is growing positive evidence[21,22]. Improving group knowledge by pre-transfer briefings would also allow better planning, early information sharing, and case-specific role assignment and contingency identification[23].The implementation of a checklist for radiology preparation during trauma activation can help mitigate coordination and communication issues[24] as well as encouragingearlier consideration of equipment and supply requirements. There is also an opportunity to examine the CT ordering process to reduce the need to re-order extra scans, and reduce the time penalty of doing so.Indeed, information technology to monitor patient waiting time, report production time, equipment maintenance and room availability has been an effective mechanism for improving patient care in radiology[25,26,27]. Though addressing patient movement in the CT is a more difficult task, this would be worth exploring by examining patient experiences further. It would appear that patients are not always informed of what is going to happen to them, and what is needed from them; further, many patients may not be fully aware and sedation is not always desirable.

The solution to any problem is likely to be more successful if multi-dimensional, so further analysis of these issues and iterative solutions would be valuable. We have found that consideration of each problem along the dimensions of people, tasks, technology, environment and organization[5] can provide a wide range of solutions to test. In this spirit, we have initiated teamwork training, debriefings, whiteboards, check lists, equipment storage standardization, communication technology and information management systems in trauma care and we will be evaluating the impact on the flow disruption metric.

Though direct observation is a powerful method for analyzing performance in healthcare systems, it has a number of weaknesses. While every effort was made to train and ensure that observers were able to identify flow disruptions, they may not have identified all disruptions. No observer was an experienced clinician, which can be advantageous for objective assessments of process, but may have limited the clinical validity of the observations. It is therefore encouraging that there was good agreement between impact scores. Some of the disruptions – especially higher order organizational and technology related issues such as the CT ordering system – may have been specific to the trauma service at this hospital. However, we suspect based on our previous experience in surgical care that many themes are universal and robust, not only across national but also international boundaries. At a minimum the observational and analytical methods deployed would be entirely appropriate for other centers.

Finally, the challenge with direct observation is to relate the processes and observed behaviors directly to patient outcomes, which we have not attempted, and would not expect to be able to

demonstrate with this sample size. Not only is this a limitation of this study, it is a general limitation of the method. Since sub-optimal processes can lead to good outcomes, and optimal processes can still lead to bad outcomes, the relationship between process and outcome is never direct. Furthermore, the heterogeneity of this patient population, and the range of outcomes they experience (from immediate discharge to ICU, OR and,on rare occasion, death) would require a prohibitively large sample size to demonstrate a statistical relationship. Nevertheless, we contend that the deleterious effects of flow disruptions offer a clear demonstration of systems problems, and that as outcomes reach asymptote, such process measures are vital for the continued development of safe, efficient care.

CONCLUSION

This prospective study,conducted at a Level-I trauma center by a team of interdisciplinary researchers to identify flow disruptions in the trauma care process is one of the first to objectively document the frequency, type and impact of flow disruption during the radiology phase. Theanalysis, using techniques common in human factors research, indicates that interventions focused on CT scanning (reducing communication and coordination failures and better controlling patients factors and external interruptions) could provide safer and more efficient trauma care. We are currently testing a range of interventions suggested by these data.

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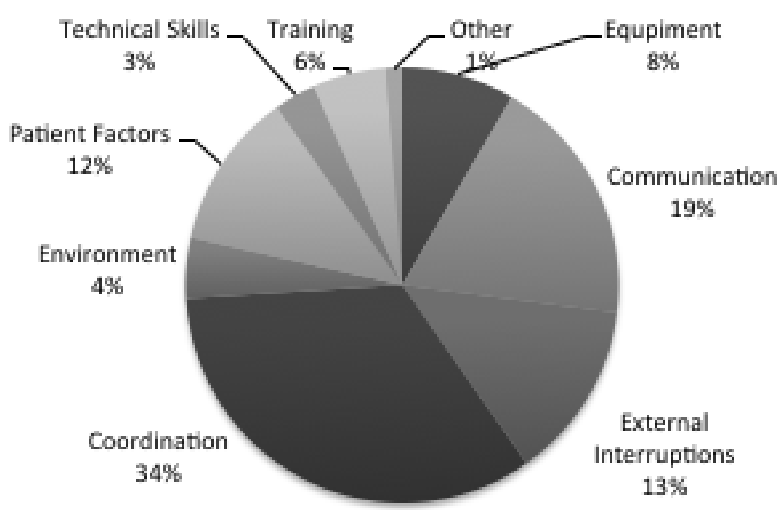

Figure 1: Relative distribution of flow disruptions.

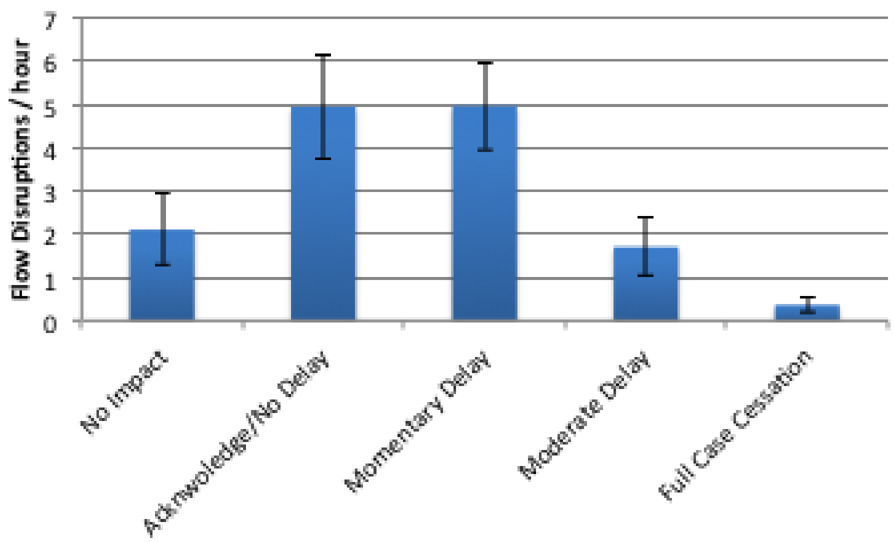

Figure 2: Observer Impact Level of Flow Disruptions

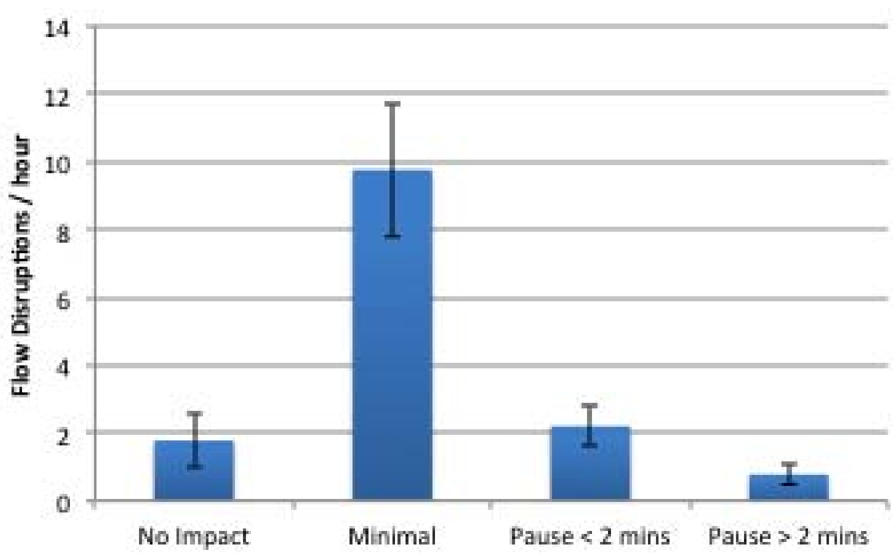

Figure 3: Clinical Impact Level for flow disruptions

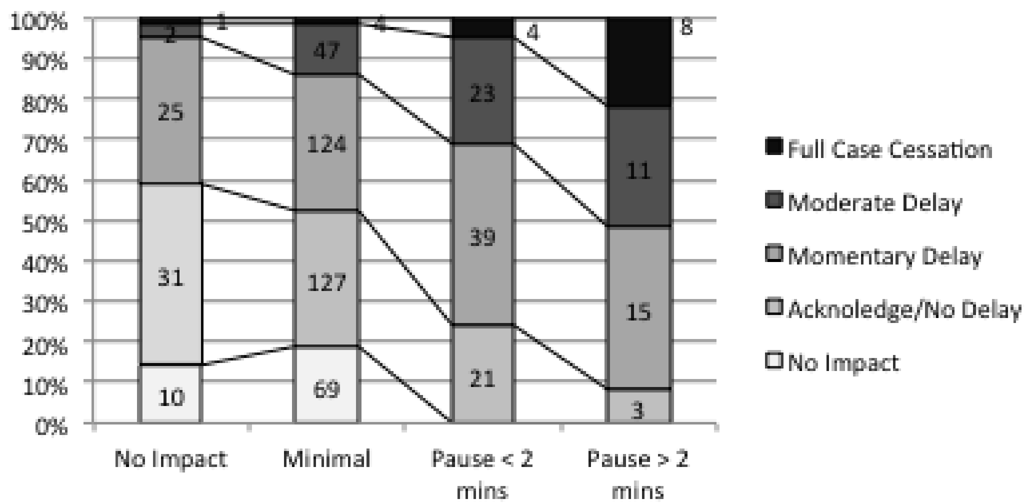

Figure 4: Agreement between clinical impact and observer impact scores.

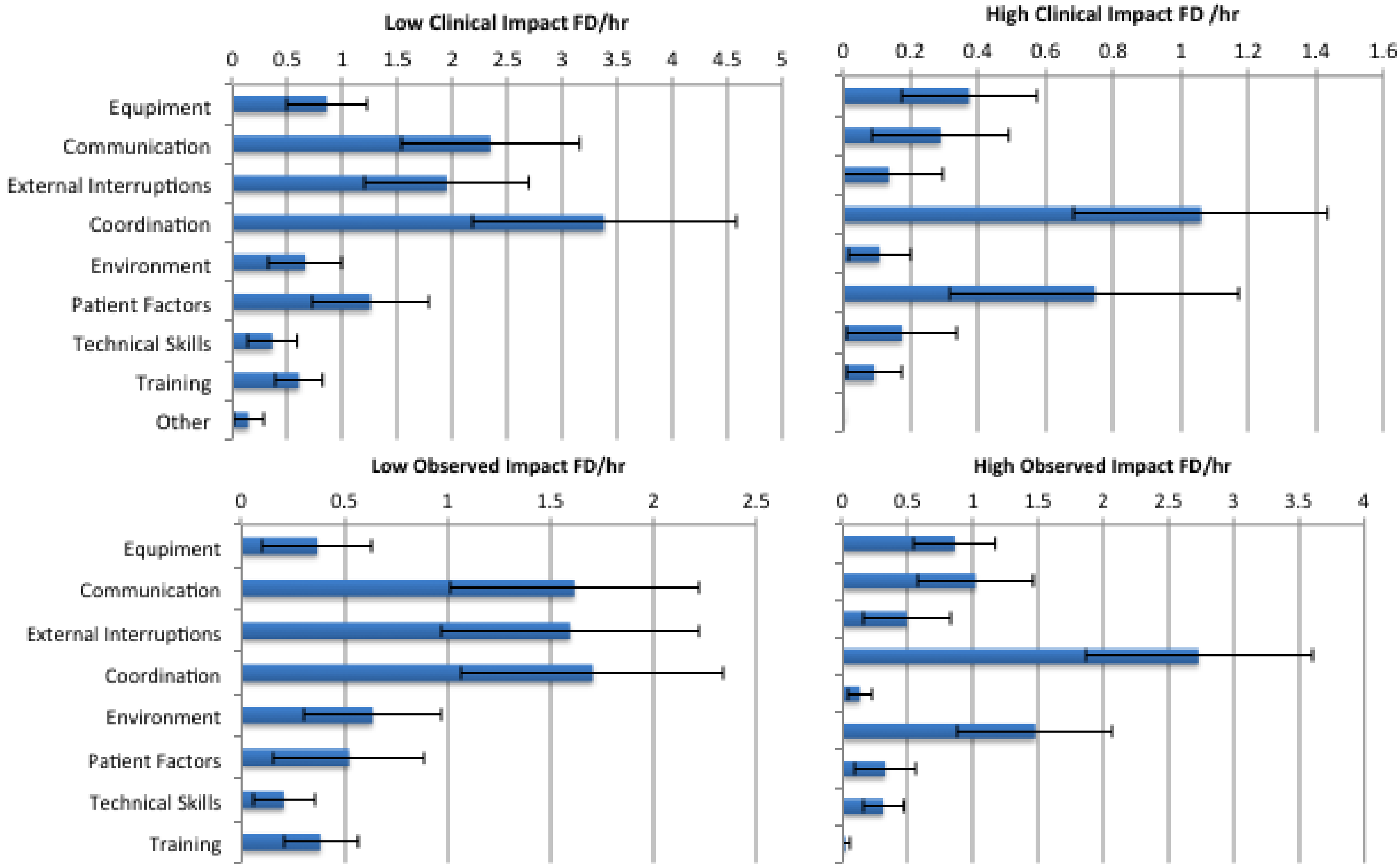

Figure 5: Clinical impact and observer impact: High vs. Low

Table 1: Flow Disruption Categories with Definitions and Examples

FD Category	Definition	Example
Communication	Disruptions that involve the verbal transition of information between at least two team members	"Nurse asked the trauma resident to speak up because too many people were talking"
Coordination	Disruptions that involve the interaction with some piece of equipment as well as at least one other team member	"Another patient was in the scanner when the trauma patient arrived at CT"
Environment	Disruptions affecting the auditory or visual status of the operating room and not directly relevant to the treatment of the patient	"X-ray tech had difficulty getting the x-ray machine into the operating room"
Equipment	Equipment problems hindering the smooth progression of the trauma team procedure	"Portable monitor was malfunctioning"
External Interruptions	Disruptions imposed on the procedure from outside, which include extraneous people, phone calls, or intercom messages that did not relate directly to the procedure at hand	"Resident's phone was ringing while he was scrubbed in the OR"
Patient Factors	Disruptions specifically involving patient-relatedfactors	"CT scan had to restart because the patient was moving
Technical Skills	Skill-based or decision (thinking) error, including poorly executed tasks, omitted steps, or misinterpretation of relevant information	"Medical student did not know how to properly connect the monitor"
Training	Training or supervision that hinders the natural progression of the trauma team procedure	"Attending was showing the resident how to perform a FAST scan"

Disruption Type	Sub-Category	n	Description of problem
Co-ordination	Wrong or Missing Orders	11	Orders for radiology must be placed by computer in the ED, and cannot be placed in the radiology department. Any additional scan requests, or erroneous requests require a team member to return to the ED, holding up the case.
	Technical Teamwork Problems	9	Getting everyone working together can be challenging with technical tasks. These problems relate to
	Team absences	7	These FDs are where unavailable team members delayed the process. Trauma teams are fluid, and members need to balance demands from different people or patients.
	CT Occupied	3	The CT scanner is a precious resource, and sometimes is still occupied when the trauma team arrive with the patient. The team has to wait in the corridor with the patient until CT is ready.
	Resource Availability	3	Medications and bloods need to be brought to the CT. Sometimes these were not available and needed to be called for.
	Other	2	
Patient Factors	Patient moving	17	Keeping an uncomfortable patient still enough to conduct required scans can be a challenge.
	Treatment required	4	Instances where the CT scan had to halt in order to give the patient treatment
	Other physiological	2	Patient needed the bathroom; and resisted transfer to the CT table.
	Other	1	
Communication	Missed/Confused Communication	6	Instances where verbal communication was mistaken or insufficiently clear for the recipient.
	Unable to contact personnel	3	Phone calls that did not connect – either because there was a different Doctor on call or they were not answering their phone.
	Other	2	
Equipment	Unavailability	7	Delays where equipment that was required was not immediately available.
	Malfunction	5	Equipment not working – either due to operator error, or maintenance problem.
	Other	3	

TABLE 2: High Impact Flow Disruptions

Flow Disruptions During the Imaging Phase of Trauma Care

Background: Due to perceived risks, going to the CT scanner is of major concern among trauma patients. Specific problems in CT, such as frequent delays and the lack of resources for airway control, have not been systematically studied. We utilized human factors analysis to evaluate the type and impact of flow disruptions (deviations from the progression of care that compromise safety or efficiency), with an explicit focus on the CT scanner.

Hypothesis: Identifying the type and impact of FD within the imaging phase of trauma care will offer a better understanding of the delays and risks associated with the CT scanner and provide opportunities to improve patient safety and system efficiency during trauma care.

Design: A prospective observational study was conducted to identify and quantify the type and impact of FD that occurred during different phases of trauma care (trauma bay, imaging and OR). This report focuses on the imaging aspect of trauma care.

Setting: The study was conducted at an 878-bed tertiary level-I hospital, located in a metropolitan area.

Patients and Methods: Seven graduate students trained in human factors principles observed 87 consecutive trauma cases over a period of two months. Observers recorded details on each FD using a validated Tablet-PC data collection tool and recorded work-system variables related to breakdowns in communication and coordination, environmental distractions, equipment issues and patient factors. The clinical impact of each FD was scored post hoc by a surgery resident and verified by an attending surgeon. FD impact was classified as 1 (none to minimal delay), 2 (moderate delay), and 3 (major delay).

Results: 77 (89%) of the 87 trauma patients were taken to the CT scanner. 1759 FD were recorded, 582 (33%) of which occurred in the CT scanner or on the way to CT. Patients spent an average of 30 minutes (SD=15 min) in the CT scanner and spent an average of 25 minutes (SD=13 min) in the trauma bay prior to arriving in CT. Among the patients that went to CT, 54% experienced a CT-related FD with an impact score of 3 (major delay). Additionally, among all the FD with an impact score of 3, 60% were associated with the CT scanner. The most common types of FD in the CT scanner were associated with coordination (34%), communication (19%) and patient factors (12%). Common descriptions of FD associated with the CT scanner include scanner unavailability and untimely movement or improper positioning of the patient.

Conclusion: This study is one of the first and largest to objectively document the frequency, type and impact of FD occurring during the imaging phase of trauma care. The implementation of focused interventions can reduce communication and coordination failures and better control disruptions related to patient factors, ultimately improving the efficiency and safety of patient care within the trauma setting.

FLOW DISRUPTIONS IN TRAUMA CARE: TYPE, IMPACT, AFFECT

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The objective of this study was to identify and understand all components of the trauma care process to mitigate the systemic challenges faced by clinicians attempting to deliver the best trauma care. The study was conducted using a prospective data collection method. An interdisciplinary team of researchers observed 90 cases over a 10-week period and identified 1844 flow disruptions. There was a higher rate of flow disruptions in the operation room (0.29 per min) than in the emergency department (0.14 per min) or radiology (0.21 per min). The majority of the flow disruptions identified had minor impacts on the system and were usually coordination issues (31%) and communication breakdowns (21%). This study demonstrated the value of using flow disruptions as a surrogate for efficiency and quality outcome measures, and as a diagnostic method for understanding higher order problems in the system of trauma care.

INTRODUCTION

Trauma care systems should be designed to ensure that severely injured patients receive the timeliest and most appropriate care. Given the complex processes, patient acuity and high temporal demand inherent to trauma care, it is imperative to understand all the components of the process to accomplish this goal. It is apparent that efficient and appropriate care improves patient survivalA study conducted by the Centers for Disease Control and Prevention (CDC) found that mortality rate could be reduced by 25% if trauma patients were seen quickly and cared for at a Level I or Level II trauma center (MacKenzie et al., 2006; CDC, 2012). This study, conducted by an interdisciplinary team of researchers, was developed to identify and understand all the components of the trauma care process in an effort to understand the systemic challenges faced by clinicians attempting to deliver the best trauma care.

Background and Framework

Prospective study methods can be used for identifying system issues in highly dynamic and complex environments such as the emergency department (ED) and operating room (OR) because they allow detection of those vulnerabilities and compensatory strategies which would not be evident from a retrospective review of patient records (Hamman, 2004 Etchells et al., 2003). Similar prospective studiesbased on direct observationshave successfully identified flow disruptions in the OR (Wiegmann et al., 2007; Henrickson et al., 2010).

Flow disruptions are defined as deviations from the natural progression of a process which potentially compromise the safety of the process (Wiegmann et al., 2007). Flow disruptions in various healthcare domains, and specifically surgical care, have been linked to medical errors (Wiegmann et al., 2007). From the systems perspective, flow disruptions are symptoms of latent failures somewhere within the system. Flow disruptions that indicate systemic failures often resurface across cases, revealing areas that warrant further investigation. The benefits of using flow disruptions as a metric include the ability to acquire a baseline measure that can be used for comparison after an intervention is implemented, and the ability to use a consistent metric acrossdiverse care environments. Most importantly, gaining a better understanding of the frequency and nature of flow disruptions allows for the development of evidence-based interventions (Wiegmann et al., 2007).

The Systems Engineering Initiative to Patient Safety (SEIPS) model was employed as a framework for understanding the sources of these flow disruptions during the trauma care process. Carayon and colleagues(2006) posit that the SEIPS Model can be employed to evaluate systemic adherence to patient safety and for designing or redesigning the system to ensure a safe environment for patients and staff. As stated by Carayon and colleagues (2006), “the structure of an organization (the work system) affects how safely care is provided (the process); and the means of caring for and managing the patient (the process) affects how safe the patient is (outcome).” The work system is comprised of five interrelated elements: (1) the tools and technology, (2) the organization, (3) the person, (4) the tasks, and (5) the environment. The breakdown of one or more of these five interworking elements is often the source of flow disruptions. Our goal was to identify the common types of flow disruptions in trauma care to aid in developing evidenced-based interventions.

METHODS

Human factors researchers andmedical studentswith training in human factorscollected prospective data during trauma cases over a ten-week period at a Level-I trauma center. The observers collected information about the trauma care process from the time the patient arrived to the emergency department (ED) until the patient was either admitted to the floor or discharged. The patients observed were all considered high level traumas requiring assistance from the in-house trauma team. Observations were conducted in multiple trauma bays, imaging rooms and operating rooms within the hospital. Multiple trauma teams were observed throughout the observation period.

Using a Tablet-PC data collection tool based on a previous version described elsewhere (Blocker et al., 2010); information about any event that disrupted the flow of the trauma care process was collected. Flow disruptions were time-stamped and categorized by observers in real time according to (1) type of flow disruption; (2) the potential and/or actual impact of the flow disruption on a scale from 1 to 5(1=no impact; 2=acknowledge/no delay; 3= momentary delay; 4=moderate delay; 5=full case cessation); (3) the trauma team member affected by the flow disruption; (4) the description of the flow disruption; and (5) the location of the observer. The flow disruption type

was categorized according to: (1) equipment (malfunctions, improper use, unfamiliar equipment, maintenance); (2) communication (misunderstanding, communication unheard, case related communication, extraneous conversation); (3) external interruptions (extraneous people, phone calls, or intercom messages that did not relate directly to the procedure at hand); (4) coordination (personnel exchanges, improperly configured equipment, not adhering to surgeon or team preferences, and requesting or providing assistance to fellow team members); (5) environment (problems with noise, temperature, lighting); (6) patient factors (disruptions related to the patient's unique anatomy such as an excessive amount of unanticipated adhesions or scar tissue); (7) technical skills (including poorly executed tasks, misinterpretation of relevant information); (8) training (teaching a new skill, correcting an improper action, posing questions to test the knowledge of the team, student, or trainee) and (9) other (not specified).

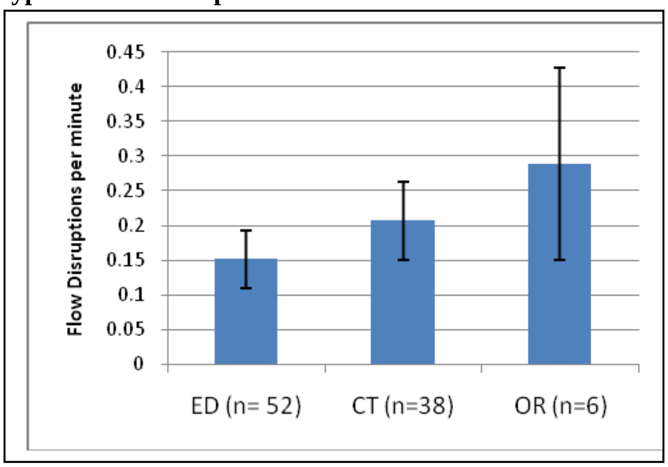
RESULTS

Frequency of Flow Disruptions and Phases

A total of 1844 flow disruptions were identified across 90trauma cases that occurred over a ten-week period. Using the times that were collected, it was possible to calculate the average rate of flow disruptions per trauma phase. The emergency department (ED) was considered the initial phase; the second phase was the radiology room, and the third phase was the operating room (OR). The mean rates are shown in Figure 1.We found the rate of flow disruptions in the ED to be 0.15 per min, radiology 0.21 per min and OR 0.29 per min.

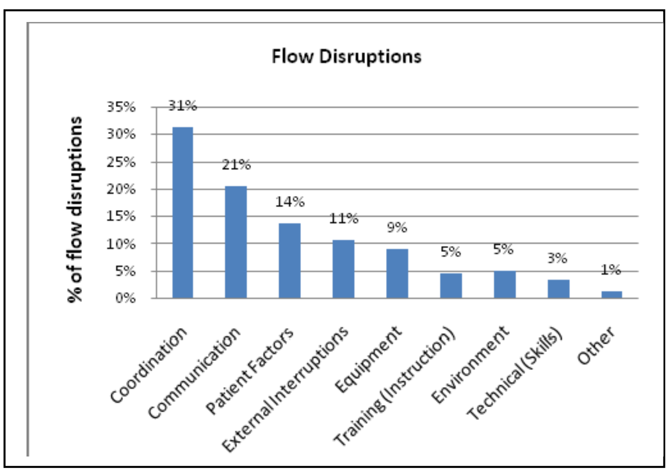
Figure 1: ED, CT (Radiology) & OR Flow Disruptions Rate with 95% confidence intervals.

Type of Flow Disruptions



Most of the surgical flow disruptions identified during the observational period were classified as unfavorable coordination issues (31%). Coordination was generally issues related to information management, collaboration, cross-monitoring and knowledge or familiarity. Specifically, coordination flow disruptions identified by the observers included the following examples from the data collected: "*trauma staff had to wait in hallway, CT (imaging) not ready because another patient is in the room*"; and "*Where's our tech at?—registered nurse needs help to move patient*". Communication (21%) and patient factors (14%) were the other most commonly identified flow disruptions by the observers. Communication flow disruptions generally involved misunderstandings or unheard statements. The flow disruptions due to patient factors were generally issues related to a patient not being cooperative because of agitation or pain.

Figure 2: Flow Disruptions Type/Percentages



Impact of Flow Disruptions/Persons Affected

The majority of the observable impacts of flow disruptions were identified as momentary delay (37%) or acknowledge/no delay (37%). There were 11% classified as having no impact, 12% classified as having moderate delay and 2% classified as full case cessation (Figure 3). The observers identified 25 of the 90 cases as having at least one flow disruption that caused a full case cessation. The observers indicated that the whole team (25%) was most commonly impacted by flow disruptions.

Nurses (24%) and residents (14%) were also frequently impacted by flow disruptions. The radiology tech (8%) attending (6%) and surgeon (6%) were impacted at a lesser frequency (Figure 4).

Figure 3: Impact Level of the Flow Disruptions

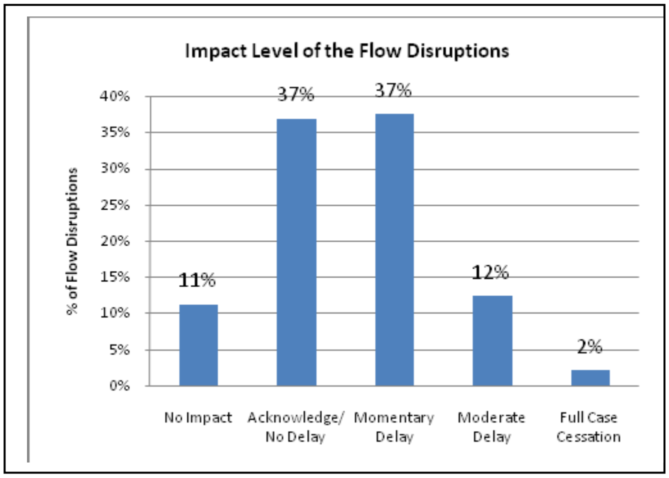
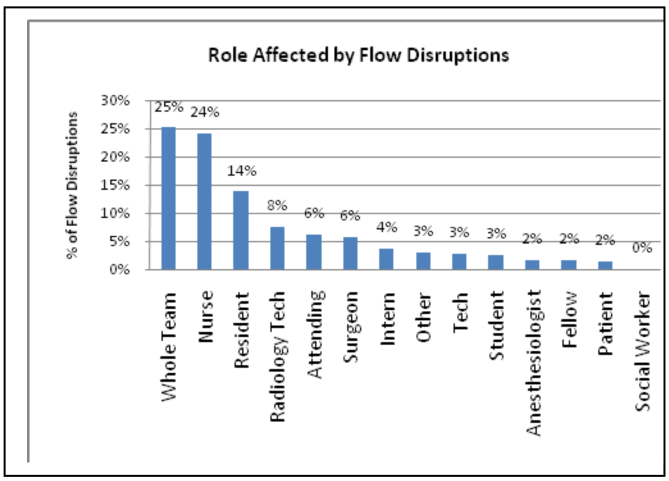


Figure 4: Role Affected by Flow Disruptions



DISCUSSION

The 1844 flow disruptions observed by our team arose from a variety of sources within the trauma care system. While most had little or no effect, occasionally they led to a complete halt in the care process. At the very least these data indicate opportunities to improve systems efficiency during the trauma care process. Moreover, these findings reflect those from other studies in a wide variety of health care settings (e.g. Duff et al., 2010; Catchpole et al., 2007; Wiegmann et al., 2007) which have demonstrated that even seemingly minor events can be detrimental to safe and appropriate patient care. Understanding the nature of the flow disruptions and their complexity is important in order to develop and implement effective quality and safety improvements.

The most frequent flow disruptions were coordination and communication issues with patient factors, external interruptions and equipment issues also contributing substantially. Coordination and communication is especially challenging in trauma care. Teams are composed of individuals from different specialties with different backgrounds and training, including many who have not worked together before. Though this is a frequent feature of healthcare teams, any weakness is exacerbated by the uncertainties and time pressures found in trauma care. We would argue that this makes teamwork and process more difficult to manage than in care settings such as elective surgery.

Another important and unique finding was that flow disruptions occurred at a higher rate in the OR than in radiology and ED. Given that patients move from ED to radiology to the OR, this suggests that as the patient moves through the trauma care process the rate of flow disruptions increases. Notwithstanding the differences in sample size, there may be several explanations for this. Firstly, only the most challenging patients are considered high level traumas. We know from previous research in surgery that higher risk operations and poorer teams have a higher volume of problems (Catchpole et al., 2007). In some cases, flow disruptions that occurred during the initial phase of the trauma care process contributed to additional flow disruptions later in the process. This additive effect has also been observed in high risk surgery (de Leval et al., 2000; Catchpole et al., 2006). We will continue to explore these phenomena, though clearly tracking the patient through the entire care process, rather than just focusing on one area or episode, provides unexplored insights into the system of trauma care that is otherwise nearly impossible to generate.

While the observable impacts of flow disruptions were identified as momentary delay or acknowledge/no delay, we argue that these minor impacts can also contribute to major impacts that may jeopardize patient care. Too many minor impacts can increase the duration of the case. Trauma patients especially require immediate care minimize the chance of further complications that can result in death. There were a lesser percentage of flow disruptions that

involved a full case cessation; however, 25 of the 90 cases involved at least one flow disruption that caused a full case cessation. While the effects of full case cessations in these25 cases may have been minor, we know that decreasing the number of minor problems can lead to a safer and smoother process (Catchpole et al., 2007).

There are a number of important limitations within our research methods. First, it is clear that inter-rater reliability is critical to the validity of the observations. Early indications are that reliability across observers is excellent, though perceptions of the importance of flow disruptions may differ with clinical background. The demands on the observers to collect a wide range of data may also suggest that refinements to the PC-based data collection tool would assist in ensuring the highest quality data. Ideally, providing this for use by clinical managers or staff for quality improvement, rather than purely for research purposes, might have substantial value.

Second, there is also considerably more analysis necessary to completely understand the systemic predisposition to error and the different causation routes and interactions between flow disruption events.

Finally, our sample also suggests that a small number of patients with the worst prognosis in the ED and the worse outcomes have a particularly high number of flow disruptions. Thus, further analysis of these specific cases would be warranted and valuable.

This work has demonstrated the value of using flow disruptions as a surrogate for efficiency and quality outcome measures and as a diagnostic method for understanding higher order problems in the system of trauma care. As we refine the methods and the analytical techniques, we believe it will contribute to a better understanding of the barriers to safe and high quality performance in trauma care.

CONCLUSION

This study was conducted at a Level-I trauma center by a team of interdisciplinary researchers to identify flow disruptions in trauma care in an effort to decrease the potential for adverse events. Several flow disruptions types and associated impacts were identified and we plan to implement a system of recommendations and then measure the interventions success. Results will provide further insight into trauma care process.

ACKNOWLEDGEMENT
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Flow Disruptions During Trauma Care

Submitted to American College of Surgeons

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INTRODUCTION: Flow disruptions (FD) are deviations from the progression of care that compromise safety or efficiency. The frequency and specific causes of flow disruptions remain poorly documented in trauma care. A prospective observational study was conducted to identify and quantify the rate of FD during different phases of trauma care.

METHODS: Seven trained observers studied a level I trauma center over 2 months. Observers recorded details on FD using a validated Tablet-PC data collection tool during different phases of care (trauma bay, imaging and OR) and recorded work-system variables including breakdowns in communication and coordination, environmental distractions, equipment issues and patient factors.

RESULTS: Researchers observed a total of 90 trauma cases including 75 low-level (trauma 200) and 15 high-level (trauma 100) activations. Eight (8.9%) cases required operations. A total of 1844 FD were recorded (20.5/case). Overall, FD frequency was highest in the OR (17.3/hr), followed by 12.4/hr in imaging and 9.1/hr in the trauma bay. Trauma 100 cases experienced a higher overall rate of FD compared to trauma 200 (p=0.063) and a significantly higher rate within the OR (p=0.033). The most common FD were coordination of care (30%) and communication (19%).

CONCLUSION: This study is one of the first and largest objectively document that FD in trauma care occur at a relatively high rate, particularly within the operating room among higher-level traumas. Further examination of the types and nature of FD should aid in the design of interventions to improve the efficiency and safety of patient care.

Comparison of FD Rate Per Hour Between High Level (100) and Low Level (200) Traumas

	Trauma 100	Trauma 200	Mean	p-Value (100 vs. 200)
Trauma Bay (FD/hr)	12.3 (95% CI, 4.8-9.8)	8.4 (95% CI, 5.8-11.0)	9.1 (95% CI, 6.6-11.6)	0.18
Imaging (FD/hr)	16.6 (95% CI, 5.8-27.3)	11.6 (95% CI, 8.0-15.2)	12.4 (95% CI, 9.0-15.8)	0.21
OR (FD/hr)	25.4 (95% CI, 16.0-34.8)	9.3 (95% CI, 6.4-12.2)	17.3 (95% CI, 9.0-25.8)	0.033
Mean (FD/hr)	14.5 (95% CI, 8.1-20.9)	9.1 (95% CI, 7.0-11.2)		0.063

FLOW DISRUPTIONS IN TRAUMA CARE HANDOFFS

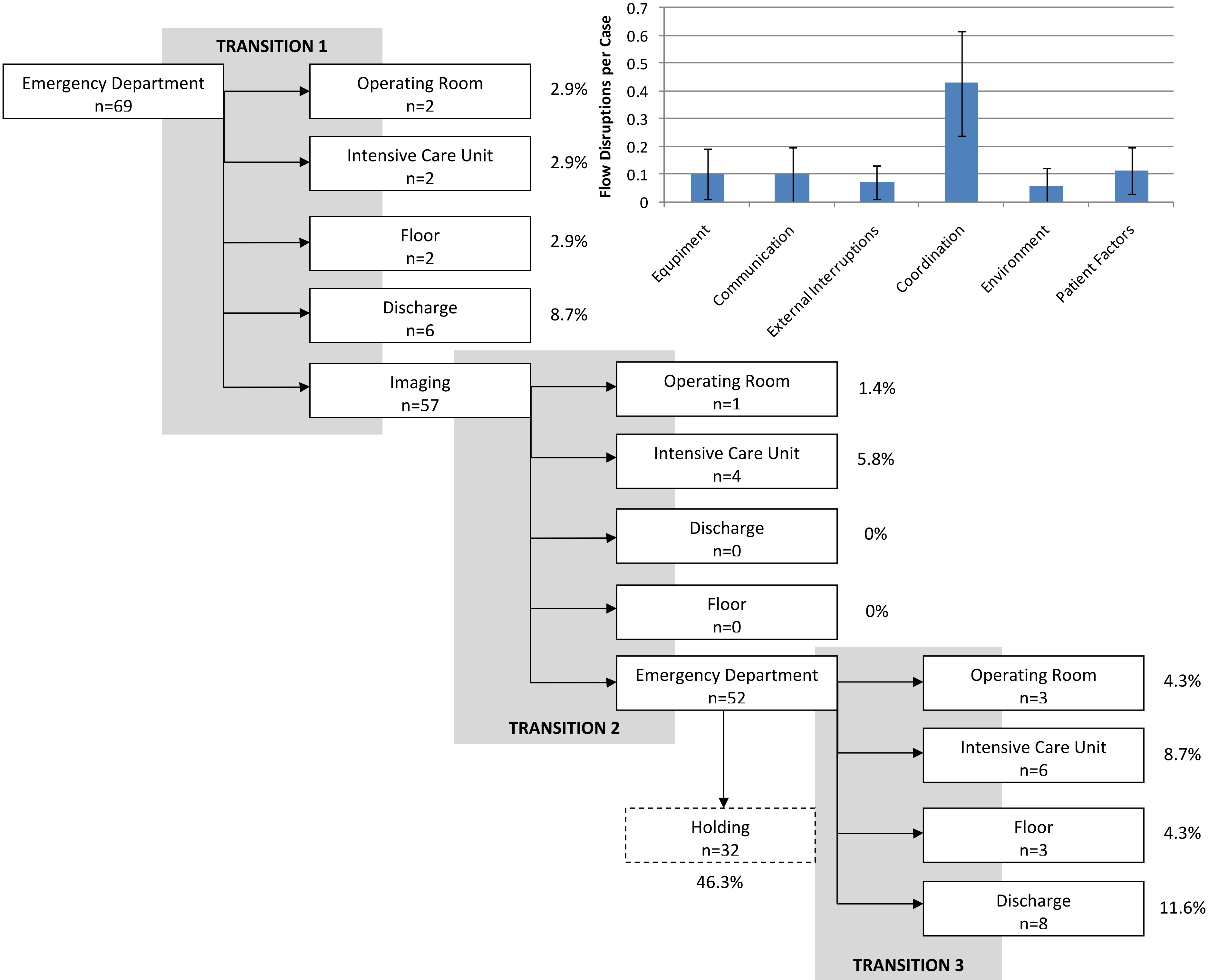
BACKGROUND: Effective handoffs of care are frequently cited as critical for maintaining safety and avoiding communication problems. Using the flow disruption observation technique, we sought to examine potential problems in transitions of care along the trauma pathway.

HYPOTHESIS: An increase in hand-offs in trauma care is associated with an increase in flow disruptions and a decrease in efficiency.

METHOD:A single observer, trained in the flow disruption direct observation technique, followed the patient from their arrival in the ED to the completion of their care. Patient flow was mapped to ascertain the different paths of care. Next, flow disruptions during the transition period were recorded and classified into one of seven categories (Equipment, Communication , External Interruptions, Coordination, Environment, Patient Factors, Technical Skills, Training, Other).

RESULTS: A total of 69 patients were studied (13high level and 56 low level traumas), and a total of 146 care transitions were observed, with flow disruptions occurring in 41% of care transitions. Of those transition flow disruptions, 30 (49%) were related to co-ordination problems. Mapping the transitions of care shows that approximately 83% of patients were assessed and transferred to imaging for further diagnostics, with 46% of patients arriving back in the ED following imaging assessment to await further consultation or discharge assessment. 7% of patients return to the ED and then are transferred to the ICU or OR. 61 flow disruptions were found during those care transitions, suggesting that on average 87% of patients experience a transition flow disruption during their care. Those patients who experienced more transitions experienced more transition flow disruptions and a longer case duration.

CONCLUSION: Transitions in trauma care, like other forms of handoffs, are vulnerable to systems problems and human errors. Reducing the number of transitions and improving co-ordination in transitions along the trauma pathway may reduce risks and improve efficiency.



Flow Disruptions per Case
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Equipment
Communication
External Interruptions
Coordination
Environment
Patient Factors
TRANSITION 1
Emergency Department n=69
Operating Room n=2
2.9%
Intensive Care Unit n=2
2.9%
Floor n=2
2.9%
Discharge n=6
8.7%
Imaging n=57
TRANSITION 2
Operating Room n=1
1.4%
Intensive Care Unit n=4
5.8%
Discharge n=0
0%
Floor n=0
0%
Emergency Department n=52
Holding n=32
46.3%
TRANSITION 3
Operating Room n=3
4.3%
Intensive Care Unit n=6
8.7%
Floor n=3
4.3%
Discharge n=8
11.6%

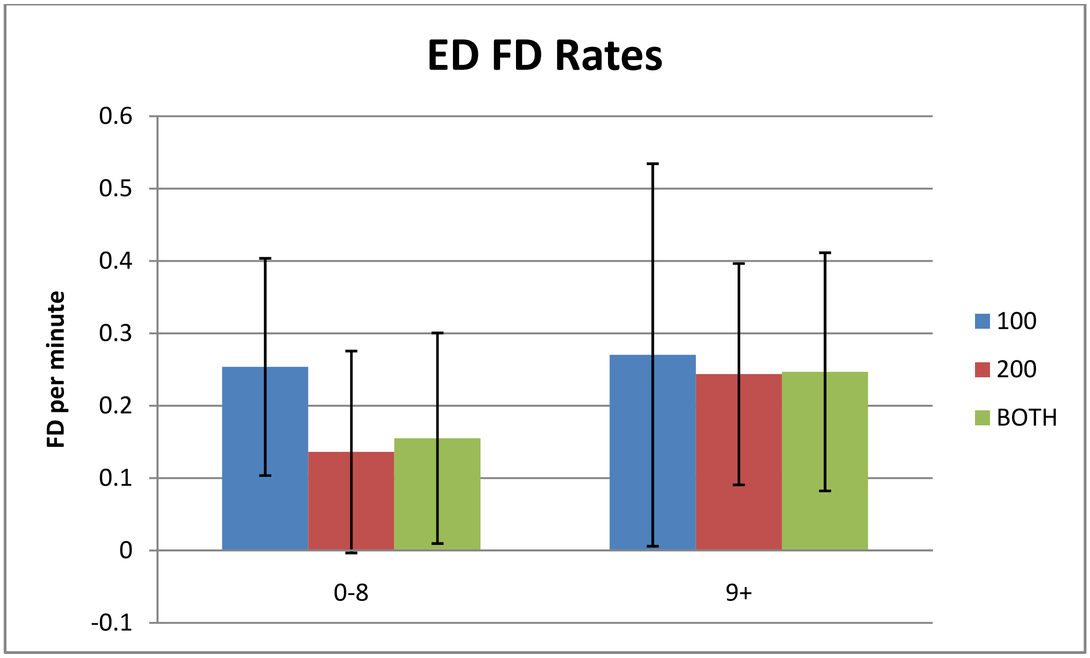
Time to Prepare Impacts Emergency Department Efficiency and Flow Disruptions

Introduction: Effective trauma care requires coordinated performance at multiple stages including "on scene" care and transport (pre-hospital phase) and care in the emergency department (hospital phase). We sought to determine if the interval between the notification of incoming trauma and the time of the patients' arrival in the emergency department ("activation to arrival time") affects the efficiency of care. We postulate that less time to prepare for patient arrival results in increases in time in the emergency department and an increased number of deviations from the natural progression of care ("flow disruptions", FD).

Patients and Methods: A prospective, observational study at a level I trauma center was conducted to identify and quantify flow disruptions at different phases of care from activation to termination of a case. Seven trained observers recorded flow disruptions in 87 consecutive trauma cases over two months using a validated Tablet-PC data collection tool and recorded work-system variables related to breakdowns in communication, coordination, environmental distractions, equipment issues and patient factors. Cases were then stratified into two groups based upon time from activation to patient arrival: 0-8 min (31 cases) and > 9 min (33 cases).

Results: A total of 87 cases were observed of which 64 met study criteria. Neither time in the emergency department (66.01 v. 61.11 min) nor overall case duration (102.78 v. 98.19 min) was affected by the time to prepare. However, a longer time to prepare (>9 min) increased the number of emergency department FD (7.74 v. 11.66, p=0.034) and ED FD per min (0.155 v. 0.247, p=0.022).

Conclusion: This study used human factor methodology to document the impact of trauma “activation to arrival” time on efficiency and FD. Our findings suggest that implementing standardized interventions that can provide system-level support for coordination and preparation of patient care may result infewer flow disruptions and safer and more efficient trauma care.



ED FD Rates
FD per minute
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
0-8
9+
100
200
BOTH

Characterizing Trauma Systems: Direct Observation of Flow Disruptions to Validate Interventions

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INTRODUCTION

- Interventions to improve trauma systems may involve communication patterns, team performance, the altered environment or equipment design. To validate these interventions the impact on the entire trauma system must be characterized. We postulate that observational methods based on human factors principles would identify unique trauma related issues

METHODS

- Data was collected from January to December 2011 to characterize deviations in the normal progression of trauma care at a civilian trauma center.
- 1. A modified version of the Safety Attitudes Questionnaire (SAQ) was distributed to 41 physicians, nurses and technicians who provide trauma care.
- 2. Focus group interviews were conducted that included 73 health care providers or allied health care staff.
- 3. Trauma teams activated for 90 high level traumas were studied prospectively by trained observers to identify flow disruptions (FD) using a validated tablet data collection tool.

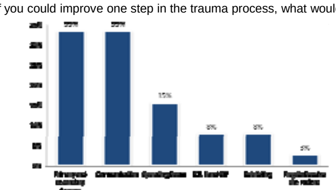
RESULTS

1. Safety Attitudes Questionnaire

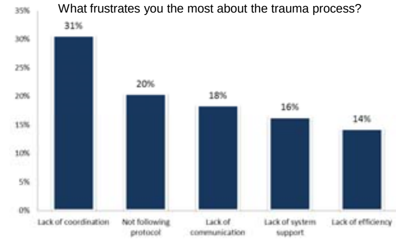
	Question	Score (mean±SD)
1.	My input is well received in this clinical area	[illegible]
2.	In this clinical area, it is easy to speak up if I perceive a problem with patient care	[illegible]
3.	The physicians and nurses here work together as a well coordinated team	[illegible]
4.	Disagreements in this clinical area are resolved appropriately	[illegible]
5.	I have the support I need from other personnel to care for patients	[illegible]
6.	I know the first and last names of all the personnel I worked with during my last shift	[illegible]
7.	Briefings are common in this clinical area	[illegible]
8.	I am satisfied with the quality of collaboration with physicians	[illegible]
9.	I am satisfied with the quality of collaboration with nurses	[illegible]
10.	I would feel safe being treated here as a patient	4.27±0.84
11.	Personnel frequently follow rules or guidelines	3.68±1.[illegible]5
12.	I know the proper channels to direct questions regarding patient safety	4.12±0.68
13.	In this clinical area, it is easy to discuss errors	3.56±1.[illegible]
14.	This clinical area is doing more for patient safety now than it did one year ago	3.54±0.92
15.	When a mistake is made but caught and corrected before affecting the patient, the situation is often reported	3.59±1.07
16.	Staff will freely speak up if they see something that may negatively affect patient care	4.10±0.74
17.	Staff feel free to question the decisions or actions of those with more authority	3.56±1.00
18.	Staff are confident to ask questions when something does not seem right	3.56±0.92
19.	Hospital units work well together to provide the best care for patients	3.59±1.07
20.	Things do not "fall between the cracks" when transferring patients	3.05±1.01
21.	Important patient care information is conveyed well during shift changes	3.42±0.96
22.	Nurses should question doctors judgment	3.93±1.05
23.	My clinical care area is efficient	3.88±0.99
24.	We have reliable and high-quality equipment	4.13±0.79
25.	During a trauma, the equipment I need is usually available	3.95±0.85
26.	During traumas, roles and responsibilities are clear	3.68±0.97
27.	We perform at a high level no matter who is on the team	3.62±1.02

2. Focus Group Interview

If you could improve one step in the trauma process, what would it be?

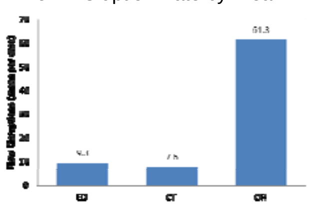


What frustrates you the most about the trauma process?

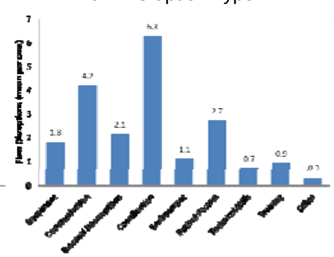


3. Flow Disruptions During Trauma Care

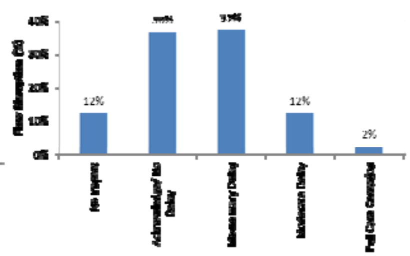
Flow Disruption Rate by Area



Flow Disruption Type



Impact of Flow Disruption



CONCLUSION

- We conducted comprehensive trauma systems reviews using available methodology to characterize common causes of inefficiency, risk and adverse events.
- Our findings indicate that objective observations based on human factors principles facilitate a better understanding of trauma systems than surveys and focus groups alone.
- Identifying the frequency and nature of flow disruptions appears best suited to validate interventions aimed at improving trauma care.

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Observation of process, teamwork and error in surgery: A measurement framework

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Funded by the Department of Defense

INTRODUCTION

Direct observation of the surgical process offers a rich method for understanding safety and performance improvement in surgical care[1]. However, little has been formalized about the methodological decisions required to enact a repeatable and valid observational study design within patient safety.

THE OBSERVATION PROCESS

(i) an event needs to occur (ii) it needs to be detected by the observer (iii) it needs to be recorded and (iv) classification may be immediate or post-hoc (v) then turned into a number in order to reach a higher level of understanding. Inaccuracies can occur at each stage. Design decisions affect these inaccuracies, results and outcomes.

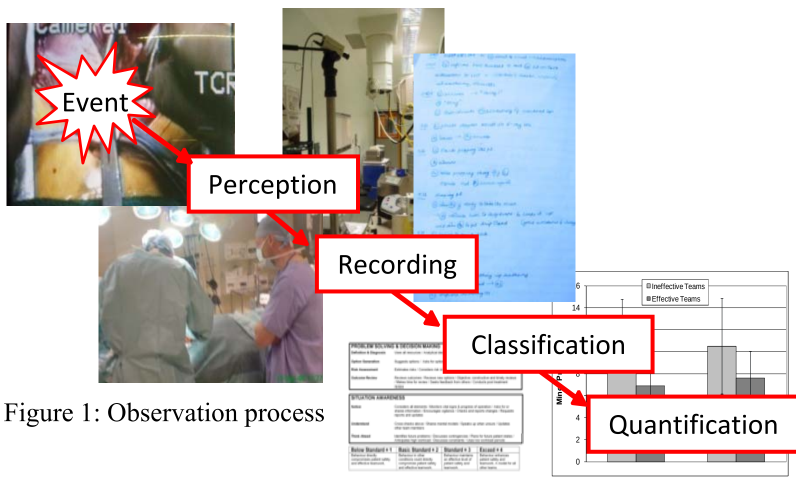

Figure 1: Observation process

WHO SHOULD OBSERVE?

Observation quality is dependent upon the design of the process and the ability of the observers to appropriately perceive, record and classify. Where do they stand? What do they do? How and what do they record? They also need sufficient clinical and human factors expertise. Our studies suggest that clinicians are more prone to classify patient and people related problems; with HF experts more likely to identify systems problems. Ensuring appropriate observer training is essential and requires reliability and validity testing

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EXAMPLE FINDINGS

Studies in cardiac surgery[3-5] have found and classified process problems that relate to risks and outcomes. In vascular, orthopedic, general and urological surgery processes and errors have been found to relate to teamwork, which can be improved through training [4,6,7]. Our recent studies have found frequent process disruptions, in trauma care, especially in the OR and imaging.

- Qualitative vs. Quantitative
- Diagnostic vs. Evaluative
- Process-orientation
- Sampling issues
- Observational structure
- Quantification process
- Observer Considerations
- Ethics

Empiricism that withstands scrutiny is the basic construct for a scientific approach, but quantitative research will not address the full complexity of surgical work. Qualitative observations may be necessary when conducting quantitative studies.

Diagnostic studies obtains prospective evidence of systemic deficiencies to predict new problems or eliminate hindsight bias. Demands a more qualitative method. Evaluative studies require tighter definition, more focus, and sufficient rigour to be repeatable.

Process-oriented tasks are easier to observe and quantify, but processes may differ unexpectedly. Many safety-critical healthcare tasks have a weakly defined process (e.g. Handoff), or have multiple ways to achieve a goal.

Frequency, predictability and repetition of the tasks to be studied defines how easily meaningful data will be collected. Highly variable processes will require a greater sample size. Rare events may need to be captured over long periods.

Highly structured observation will ease the classification and quantification; but may miss key safety and quality issues. Observers need cues (e.g. Behavioral markers [2])

Large data sets can be captured. Some have measures that need to be organised; others tell powerful stories. Extrapolating to deeper systemic causes is challenging. This process defines the value of the conclusions.

Observation can affect behavior of those being observed. Observers need to be sensitive to operational needs, may not be welcomed, and events observed can be traumatic.

Observation falls outside traditional medical ethical guidance. How and when should an observer intervene; and what is the medico-legal status of observer and their data?

VALIDATION OF OBSERVATIONS

Processes with unknown effects on outcome are observed frequently. Correlation with clinical impact, or identifying errors and safety issues, is challenging. To frame and validate observations, ask:

Is this consistent with achieving a high standard of care?
Would this be acceptable for me or one of my family members?
Does it have to be like this?
Is this the best it can be?

Then compare and discuss experiences widely

Then publish & present

And feedback into healthcare

CONCLUSIONS

A decade of observational research, in cardiac, vascular, general, orthopedic and trauma surgery, with human factors, surgical, and anesthetic experts, has improved our understanding of how observational methodologies can be developed appropriately for research and quality improvement. It is time for a structured and generalizable approach to observational data collection in surgical care.

Transactive Memory Systems and Coordination in Trauma Care

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INTRODUCTION

High performance, high-reliability teams are often made up of members who possess specialized expertise, are interdependent with regard to task completion, may be rapidly formed, and have a highly fluid composition. These teams often work in technology rich environments with dynamic conditions, significant time pressure, and must coordinate across several physical and organizational settings. These conditions are all present in trauma activation teams. The volume of information, skills, and knowledge necessary to successfully perform the essential tasks during activation is too great to be held by any one individual, making effective and efficient teamwork essential to performance.

The study of transactive memory systems was first introduced by Wenger (1976), to describe how intimate couples create and maintain informal but stable knowledge structures based on the understanding of each others' respective areas of expertise and utilize this system for the management of information. More recently, researchers have been interested in transactive memory systems (TMS) to better understand and predict group behavior through an understanding of the manner in which groups process and structure information. A transactive memory system is developed within teams to facilitate the cooperative division of labor for learning, remembering, and communicating relevant team knowledge. The TMS describes the process by which teams encode, store, and retrieve information.

OBJECTIVE

The objective of this paper is to analyze instances of disruption during the trauma care process related to coordination to identify the presence of a functional transactive memory system in use by trauma teams. If the existence of a TMS is supported, interventions can be tailored to best facilitate and strengthen TMS.

METHODS

Researchers collected prospective data during 90 trauma resuscitations over a ten-week period at a level-one trauma center. Information about any event that disrupted the flow of the trauma care process was collected including the type of the disruption, its impact on the process of care, and a qualitative description of the event. Based on the relationships suggested by the TMS construct, the manifestation of a solid TMS will be specialized knowledge distributed across team members, smooth, efficient coordination. Researchers analyzed disruptions attributed to coordination by extracting information pertaining to the use, request, or absence of specialized information and/or the location where this information could be accessed.

TRANSACTIVE MEMORY SYSTEMS

Transactive memory systems are developed through an understanding of others' expertise or specialization, the credibility that can be extended to them, and an understanding of how best to coordinate with and complement one another as decisions are made and tasks are performed. Behavioral hallmarks of teams with a strong TMS are: evidence of specialized knowledge, awareness of and trust in other members' expertise, and smooth coordinated task processes. Coordination is facilitated by the existence of specialized knowledge, and an understanding of where to locate this knowledge. Instances of poor coordination likely occur due to deficiencies in one of these components.

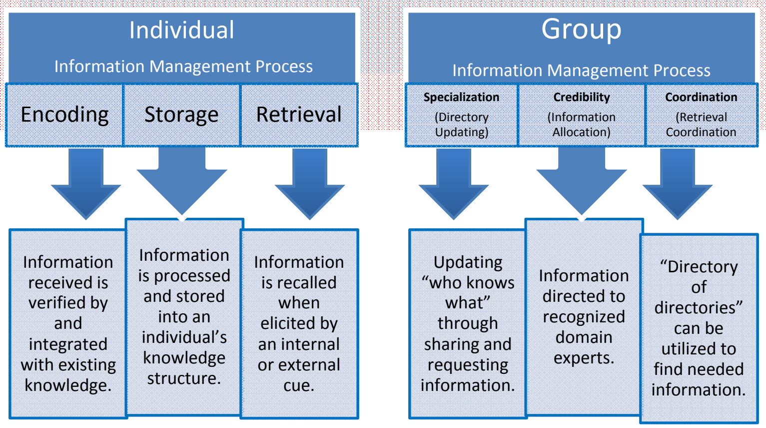

Figure 1. Parallel and divergent properties of individual vs. group information management processes

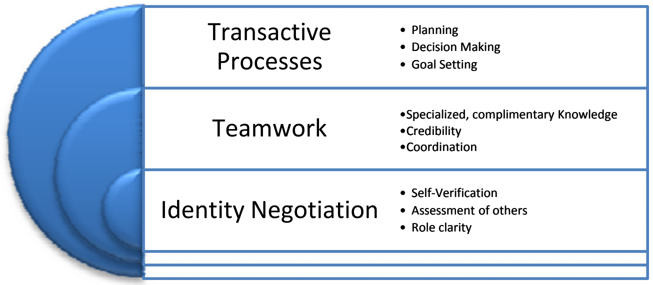

Figure 2. Transactive emory system components

RESULTS

Observational data revealed that coordination breakdowns (n = 427) occurred more frequently than any other type of disruption. The description of each coordination disruption was analyzed to extract information pertaining to specialized knowledge and the knowledge of the location of that information. Based on this analysis, four themes were identified that suggest that disruption data related to coordination may be useful for determining the existence, value, and strength of TMSs in high-reliability teams. These themes are: (1) Information management, (2) Collaboration, (3) Cross-monitoring, and (4) Familiarity. The conceptual parallels between the themes identified from the coordination disruptions collected and the concepts described by the TMS framework support the pursuit of further analysis and interventions aimed at fostering strong transactive memory systems.

CONCLUSION

Flow disruptions identified during the trauma care process related to coordination The TMS framework holds promise as a means of differentiating high and low performing teams, and diagnosing deficiencies that may be impeding the development and utilization of TMSs. This type of analysis can help organizations predict and prevent knowledge underutilization with insight regarding the impact of team composition, complementary expertise, and delegating information responsibility. Insights gleaned from ineffective coordination practices reveal implications for interventions and interpretations based on the TMS framework.

LIMITATIONS

The goal for this analysis plan was to determine if the use of the transactive memory systems as an underlying mechanism of teamwork could be determined through evaluating the descriptions of instances of coordination breakdown. While the data sufficiently supported this endeavor, additional analysis is necessary to determine how to best translate this understanding to a specific intervention.